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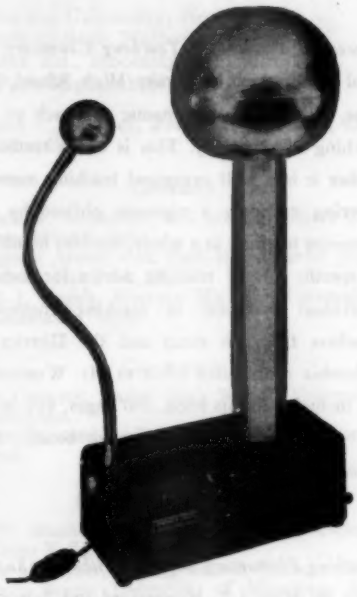

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A Popular Fallacy

Brother T. Brendan, F.S.C.
Saint Mary's College, California

When students take their first serious mathematics courses, they often experience a real thrill at the power and beauty of the indirect proof or so-called proof by contradiction. Unfortunately, they sometimes attempt to extend and adapt this method of proof in ways that are invalid.

One way that they rationalize their efforts is often this: "We know that the indirect proof proceeds by first assuming the falsity of a proposition which we want to prove true, and then, after suitable manipulations on the basis of the assumption, trying to *arrive at some obvious contradiction*. If we succeed, we have shown that the assumption was incorrect and so we have proved that the original proposition is true. Now why not invert this process? If we are faced with a difficult proposition, suppose we assume the proposition is true, and then, by suitable manipulations on the basis of this assumption, we *arrive at some obvious identity*—which 'clearly proves' that the original assumption was correct; that is, we have succeeded in showing that the proposition assumed to be true is true." Moreover, the students argue, this is effectively what we do in many mathematical situations. When we have a trigonometric formula to verify, we write it down and then reduce it by suitable operations to some obvious identity.

Using symbols from logic, we may write one form of the *valid* indirect proof of a proposition p from a hypothesis q as follows:

$$[q \wedge (\sim p \rightarrow \sim q)] \rightarrow p.$$

This logical formula is verified by a truth table such as

p	q	$\sim p$	$\sim q$	$\sim p \rightarrow \sim q$	$q \wedge (\sim p \rightarrow \sim q)$	formula
T	T	F	F	T	T	T
F	T	T	F	F	F	T
T	F	F	T	T	F	T
F	F	T	T	T	F	T

The last column clearly indicates that this kind of indirect proof is a satisfactory tautology. Now if we attempt to verify the second kind of so-called "proof" in the same way, we may let I stand for the concluding identity; i.e., if the "proof" arrives at some obvious identity $q=q$, call it I. Then the "proof" becomes $(p \rightarrow I) \rightarrow p$. Setting up the table (which will have only two rows since I, as an obvious identity, is always true), we get

p	I	$p \rightarrow I$	formula
T	T	T	T
F	T	T	F

Thus the formula is clearly not a tautology.

These remarks are not of much use to the teacher, however. Appeals to logic and the apparatus of truth tables seem to lack pedagogical force. Especially is this so if the students have had teachers or textbooks which gave them constant bad example! I have yet to find a college freshman class in which everyone was immune to the temptation of using the above easy "proof." Other instructors have corroborated this experience.* K. O. May and M. Richardson have written about this matter, the former very briefly and the latter without complete clarity. (See the references at the end of this article.)

What we blame is the bad example to which our students are exposed. For instance, here is a typical case from trigonometry (chosen from a well-known college freshman text which prides itself on the modern approach and on its chapter of mathematical logic!). It is clear that the author does what most authors do: starts with the statement to be proved and then proceeds to an obvious identity.

A. *"Show:*

* I am indebted to Professor J. A. Sullivan of the University of Notre Dame for calling my attention to the situation some years ago and for providing one of the examples in this note.

$$\frac{\sin^2 x}{1-\cos x}=1+\cos x,$$

provided that $1-\cos x \neq 0$.

Solution: Since

$$\sin^2 x=1-\cos^2 x,$$

we have

$$\frac{1-\cos^2 x}{1-\cos x}=1+\cos x,$$

so that

$$\frac{(1-\cos x)(1+\cos x)}{1-\cos x}=1+\cos x,$$

or, finally,

$$1+\cos x=1+\cos x,$$

provided

$$1-\cos x \neq 0."$$

This is the familiar technique of reducing to an identity by perfectly legitimate substitutions and operations, starting from the statement to be proved. But, as shown above, it is not always a valid procedure.

Probably the best way to convince students of its invalidity is by counterexample, that is, to illustrate the fallacy of the technique by applying it to a patent absurdity. I have tried this in the classroom for several semesters with good effect. Thus,

B. *Show:* For all x real,

$$\sin^2 x = 1.$$

Solution: Multiply both sides of the statement by the quantity

$$(1-\sin^2 x-\cos^2 x),$$

giving

$$\sin^2 x-\sin^4 x-\sin^2 x \cos^2 x=1-\sin^2 x-\cos^2 x$$

or,

$$2 \sin^2 x-\sin^2 x(\sin^2 x+\cos^2 x)=1-\cos^2 x$$

or, since

$$(\sin^2 x+\cos^2 x)=1, \qquad 2 \sin^2 x-\sin^2 x=1-\cos^2 x$$

or,

$$\sin^2 x+\cos^2 x=1$$

or,

$$1=1,$$

an obvious identity.

And consider a better known case from algebra:

C. *Show:* $3=4$.

Solution: Substracting $7/2$ from each side gives

$$(3-7/2)=(4-7/2),$$

so that

$$(3-7/2)^2=(4-7/2)^2$$

or,

$$9-21+49/4=16-28+49/4$$

or

$$9-21=16-28$$

or,

$$-12=-12,$$

an obvious identity.

Of course it is easy to see the difference between exapmle A, chosen from the trigonometry text, and these last two examples, B and C. The solution for A *is* indirectly or implicitly valid, that is to say, it is valid only because each of the operations from step to step is reversible, so that it would be possible to start the proof from the other end (i.e., to start with the final identity) and to work backwards using the inverse operation at each step—thus arriving at the desired proposition. In examples B and C this reversing process would break down at one step or another. Thus, while multiplication by zero is legitimate in example B and shows that $p\rightarrow I$, the inverse operation of division by zero is not legitimate and would not show $I\rightarrow p$. Similarly in example C, while a difference in signs disappears under the squaring operation, we would not recover this difference in the reverse process.

My complaint is that these matters are not somehow made clear to our students, and so through no fault of their own they are led into the false logical position that I mentioned at the beginning. I would urge trigonometry textbook-writers to prove some of their

identities in the *reverse order* to that used in present practice and to show the logical necessity of such reversibility. This amounts to making it clear in some way that for a proposition p and an obvious identity I, $(p \leftrightarrow I) \rightarrow p$ is a tautology while $(p \rightarrow I) \rightarrow p$ is not. Compare this table with the earlier one:

p	I	$p \leftrightarrow I$	formula
T	T	T	T
F	T	F	T

The comparison shows that the reversibility is logically *essential*.

Some readers are sure to complain that this is a great deal of fuss to make over a technical point that can arise only in one or two cases in high school anyhow—namely, in squaring or in multiplying by zero. And it may be true that the only examples that occur in high school mathematics are like the two trivial examples B and C above and that they can be proscribed easily by enunciating a rule or edict (that is to say, by sheer dogmatism) rather than by careful analysis of the fallacy involved. But such is not the case in college mathematics, and many college teachers have a serious pedagogical problem on their hands as a result of the earlier carelessness.

References

May, Kenneth O.; "What Does 'If' Mean?" *Mathematics Teacher*, Vol. 48, #1 (January, 1955). Pp. 10–12.

Richardson, Moses; *Fundamentals of Mathematics*, Revised Edition, 1958. Macmillan. Pp. 120–121 and 123–124.

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Improved Gas Law Apparatus

John Noehl

Franklin High School, Portland, Oregon

The gas laws can represent one of the high points of a high school physics course. One can develop a model on the theoretical level and then find justification for the theory in the laboratory. The model can be built from assumptions concerning the nature of matter and a suitable application of physical principles from mechanics.

The assumptions can be given credence by simple demonstrations. For example: demonstrations of expansion when a liquid changes to a gas indicates that the molecules of a gas must be widely separated. Demonstrations with diffusion and Brownian motion give evidence of molecular motion. Direct measurement establishes that the molecules of gas have mass, etc. Combining assumptions, evidence of molecules and their nature, physical principles and some simple logic one can arrive at the relationship between the pressure, volume, temperature and number of molecules in a gas. This relationship is $PV=nkT$, where k is a constant with the units ergs/degree, when P is in dynes/cm.^{2}, V is in cm.^{3}, n is the number of molecules in the gas sample and T is the temperature in degrees Kelvin.

If for a particular sample of gas we keep the temperature constant then the equation can be rewritten as $PV=b$, where $b=nkT$. This equation is of the form $xy=k$ which is the equation of a hyperbola with the coordinate axis as asymtotes.

The next step in this sequence is to attempt to justify the theory by means of suitable laboratory work. Normally this is done with a J tube: here the trouble begins. A graph of the values of V plotted against corresponding values of P, usually result in a straight line instead of the desired hyperbola. The reason for this is that the pressure can vary over a range from one atmosphere of pressure to two or three atmospheres pressure, and this only gives the data for one arm of the hyperbola which approaches a straight line. It is obvious that an apparatus that would allow us to vary the pressure from less than one atmosphere to more than one atmosphere would be better suited for our purpose. Fig. 1 shows a simple piece of equipment which meets the preceding requirement.

The apparatus consists of a glass tube with an inside diameter of approximately 2 mm., and about 36 inches long. A column of mercury approximately 30 cm. long is introduced into the glass tube and one end of the tube is sealed. The tube is fastened to a meter stick.

Two precautions are necessary. First, the tube and the mercury must be clean. Second, the apparatus must not be subjected to any sudden shocks since this will separate the mercury column.

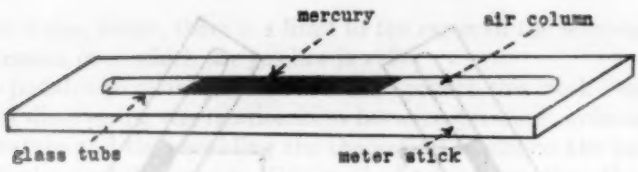

FIG. 1

The data can be collected as follows: When the apparatus is in a horizontal position (see Fig. 1) the pressure on the trapped gas in the tube is equal to atmospheric pressure (P_{atm}). Raising the closed end of the glass tube will cause the pressure on the trapped gas to be lowered. The force exerted by the trapped column of mercury is in a direction opposite to the force exerted by the atmosphere. The pressure (P) is equal to $P_{atm}-h\times13.6\times980$ dynes/cm.[2] Reference to Fig. 2 shows that $h=\text{L}\sin\theta$, or $P=P_{atm}-13.6\times980\times1\sin\theta$. The tube is rotated from 0 to 90°. Next, with the open end of the tube raised, data is collected through the range 0 to 90°. Reference to Fig. 3 shows that the pressure on the gas is now equal to $P_{atm}+13.6\times980\times\text{L}\sin\theta$ dynes/cm^2. (L=length of mercury column.)

The data is plotted and will now be found to give the desired hyperbola.

The data can be evaluated by an alternate method. Dividing $PV=b$ by V we obtain $P=b(1/V)$. This is an equation of a straight line with a slope equal to b. The value of b is obtained from the graph and using values of n and T, k is then computed. Typical student results with this experiment give values of k within 2% of the accepted value.

The relationship between volume and temperature, when the pressure is constant, can be determined using the apparatus in Fig. 4. This apparatus consists of a glass tube approximately 20 cm. long and 2 mm. inside diameter with a 1 cm. column of mercury trapped inside. One end of the tube is sealed off and the glass tube is secured to a 20 cm. metric rule. The apparatus is weighted and placed horizontal in a pan of water so that it is totally submerged.

The temperature of the trapped gas in the tube can be varied by heating or cooling the water in the pan. A large quantity of water enables the experimenter to control the temperature more accurately. The temperature of the trapped gas equals the temperature of the water, therefore, can be measured with a suitable thermometer. The corresponding volumes can be read off the metric scale. The pressure on the trapped column of air is essentially constant throughout the experiment and approximately equal to atmospheric pressure.

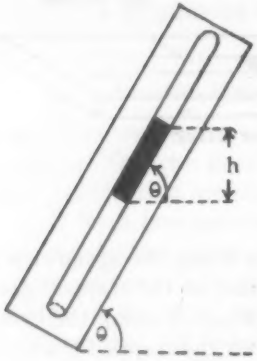

FIG. 2

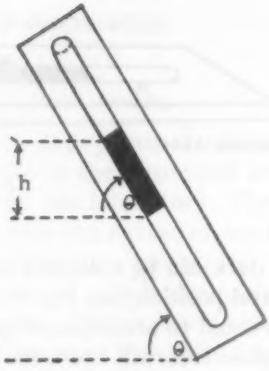

FIG. 3

Graphing V against T demonstrates that the volume varies directly with the temperature. This can be expressed mathematically as $V=(nk/P)T$. k is evaluated from the graph.

Extrapolating the graph until $V=0$ leads into a discussion of absolute zero and its interpretation. This leads to a theoretical development of the relationship between temperature and the average kinetic energy of the molecules in the gas with the consequent interpretation of what is meant by temperature.

The work on the gas laws can be concluded with a small thought experiment. At a particular pressure and temperature any sample of gas that we use will have the molecules close enough together and moving at slow enough speeds so that the gas will become a liquid. The assumptions made in our theoretical development were valid

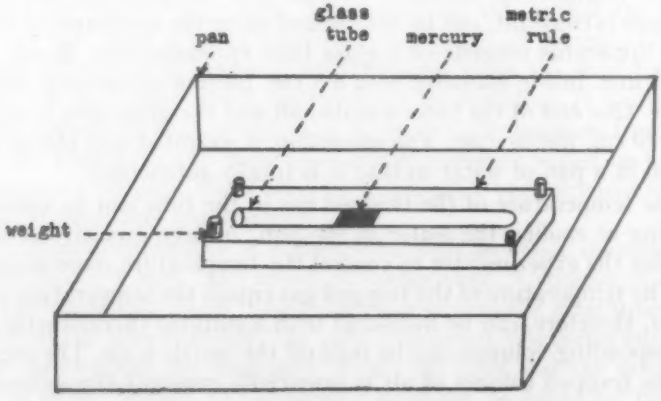

FIG. 4

only for a gas, hence, there is a limit to the range of the temperature and pressure over which the gas law is valid.

It is possible to allow the students to approach this work from the point of discovering the relationships between pressure, volume and temperature and then building the theoretical model on the basis of the experimental discoveries. This method takes more time than the other, but at the same time it seems more rewarding in terms of the students' attitude and achievement.

The preceding development of the gas law allows one to build a beautiful theoretical model which over the range of available experience (high school physics lab) holds up well. In addition, it demonstrates the value and need for mathematics in interpreting and describing physical phenomena.

JOHN HAY FELLOWSHIPS FOR 1960–61

Public secondary school teachers in seventeen states and the District of Columbia are invited to apply for John Hay Fellowships for a year of study in the humanities at one of six universities: California, Chicago, Columbia, Harvard, Northwestern, and Yale. Stipends are equivalent to the teacher's salary for the year of fellowship and provide tuition and round-trip transportation. Participating states for 1960–61 are: Arizona, Colorado, Connecticut, Illinois, Louisiana, Maryland, Massachusetts, Michigan, Missouri, New York, North Carolina, Ohio, Oregon, Pennsylvania, Utah, Virginia, and Washington, as well as the District of Columbia. Approximately 80 grants will be made for 1960–61.

The John Hay Fellows Program is designed to help outstanding teachers broaden their intellectual horizons through study and reflection. Fellows return with greater resources for helping their school systems to carry out imaginative and creative programs for both teachers and students.

To be eligible for candidacy, a man or woman must (1) hold a minimum of a bachelor's degree from an accredited college or university; (2) have at least five years of high school teaching experience, the most recent two of which shall have been in the present employing system; (3) be not over fifty years of age at the time aplication is made; (4) be a permanent instructor whose major responsibility is classroom teaching at the high school level; (5) be employed in a school or school system which is not only academically sound but which has also shown its interest in effective use of unusually good teachers; (6) be nominated by the employing Superintendent of Schools or other authorized nominating official.

Although subjects such as foreign languages, literature, history, music, and the fine arts are usually considered the humanities, nominations of teachers in other areas—especially the social and natural sciences—will be accepted.

The John Hay Fellows Program was established in 1952 by the John Hay Whitney Foundation of New York City. In the spring of 1958, a two-year grant from the Ford Foundation not only increased the number of grants substantially but also made possible a new feature of the Program, that of summer institutes in the humanities for high school teachers and administrators.

Sixty-three Fellows are currently beginning their fellowship year. One hundred and twenty-eight teachers have completed a year of study as John Hay Fellows.

Information and application blanks for 1960–61 Fellowships may be secured by writing to Dr. Charles R. Keller, Director, John Hay Fellows Program, 9 Rockefeller Plaza, New York City, New York. Applications close on December 1, 1959.

A Few Significant Factors in the History of Science Teaching and the Possible Cause and Effect Relationships Between These Factors and Present Problems in Teaching Grade and High School Science*

Harry A. Cunningham

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We will briefly consider a few aspects of the following three points: (1) how to train prospective elementary and high school teachers in science, so that they can teach effectively the science in the first eight grades and in the high school; (2) how to give further help to those who feel themselves inadequately prepared, as teachers, in the elementary and high school; and (3) what kind of science should be taught in the elementary and high school and how should it be taught. These problems are always with us.

As we proceed in our brief discussion of the above problems, three other basic considerations will continually appear. These three questions are: (1) Is it necessary to sanction wholeheartedly either the philosophy of Plato or that of Dewey? (2) Should we retain the scientific method not only as the method used in the determination of what shall be taught in science and how it is to be taught, but also shall we retain the scientific method as one of the major objectives of science teaching? and (3) Do we need to continue to commit ourselves rather wholeheartedly to the organismal theory? Our point of view on the last three items has influenced what has been done on the first three problems and such influence will certainly continue.

We will consider two major factors in the science requirements for prospective teachers in the elementary and high school: (1) the state certification agencies; and (2) the science requirements for graduation set up by the colleges and universities. A great advance has been made in raising standards through higher certification requirements since 1909 when the writer received his first teaching certificate before having attended high school. The certificate was granted after an examination, given at the county court house, was taken and passed. The writer taught with this certificate in a country school for two years after having attended high school one year. Good work on this certification problem is being done in almost every state by the cooperative efforts of scientists, educators, and representatives of the various State Departments of Education. Dr. John R. Mayor, Director of the Science Teaching Improvement Program of the American Association for the Advancement of Science, says that considerable

* Vice-presidential address read at Washington D. C., December 28, 1958, at a session of Section Q of the annual meeting of the American Association for the Advancement of Science.

cooperation between scientists and educators is being practiced in this area.[1] This cooperation has at times been difficult to obtain. Dr. Mayor writes that "Academic people know, first of all that they can best achieve their aims by working with professional educators and classroom teachers much more than they have ever done; they also know that if they do this, they will be more sure whether what they think they want is reasonable and possible to obtain."[2]

This is a good example of the cooperative thinking that must go on, not only between scientists, educators, and laymen, but also between local and national levels—between the parts and the whole. This cooperative work is democracy; it is also evolution.

In the judgment of the writer, certification requirements in science, while important, take on secondary significance to the science requirements for graduation of prospective elementary school teachers and for major requirements for prospective high school teachers, from the college and universities. These standards of the colleges and universities in our state are always higher than those of the State Certification agency. In Ohio the certificate is granted by the State agency only upon recommendation of the college or university granting the degree.

Both the quantity, the quality, and the appropriateness of the science courses given these prospective teachers in their under-graduate work becomes of great importance and concern. At this point we scientists should show a high degree of humility and anxiety to learn even from the educators. Many of my fellow scientists and other scholars in the colleges of Arts and Sciences have maintained that the educators are insisting that too great a proportion of the undergraduate work is required in education at the expense of science courses. This may be true in some cases, but it is certainly not universally true. The vigorous, often vicious, attacks of some scientists and other scholars against our schools might have seemed a little more reasonable and have been received a little more gracefully if these same scientists and scholars had, over a period of years, shown more of a sustained, helpful, and sincere interest in the problems of our schools. More concern by the scientists needs to be given to the preparation of suitable science courses for prospective teachers, both grade and high school. College science courses suitable for pre-medics are often not suitable science preparation for teachers.

In a study of this problem by a committee for the Ohio Academy of Science, of which the writer was chairman, it was found that high school science teachers were well prepared in at least one science

[1] John R. Mayor, "Science Teaching Improvement Program," *Science*, 128: 1262–1265, November 21, 1958.

[2] John R. Mayor, "Science Teaching—Problems of Quantity and Quality," *The Educational Forum*, 21: 149–157, January, 1957.

field, and many had more than the minimum requirements for a major.[3] Most science teachers on temporary certificates lacked permanent certificates because they lacked education requirements, not because they were lacking in science credits.

Our second problem deals with the proper courses in science and other help needed for elementary and high school teachers who are teaching and already have a bachelor's degree. This problem is especially critical for the elementary school teachers because (1) science in the elementary school is a relatively new course; (2) physical science in the elementary school is more new; and (3) the idea of beginning in the elementary school to teach for the partial understanding of principles is most new. None of the special agencies, such as the National Science Foundation, have, so far as the writer knows, offered help in science to these needy elementary teachers. The significance of this is not fully realized.

To some extent the basis for future study in science should now be laid in the elementary school. Certainly the favorable or unfavorable attitudes toward science of these young people when they enter high school is very important. These needy elementary teachers are not only not being helped by special agencies that are doing such an admirable job in helping high school teachers, but these elementary teachers find it very difficult at our colleges and universities to get suitable courses in proper amounts and given at suitable times to take in order to remedy their science shortcomings. These teachers need to get a master's degree or its equivalent. They need more credits to get more pay. They probably need a master's degree to enhance their feeling of being of some importance in the school and in the community. In our state, they need a fifth year of work in order to get a permanent certificate. Many need this additional work in science. Where and how are they to get this additional work?

Ninety percent of the master's degrees earned by these people in Ohio are earned in education. Some of my colleagues in science throw up their hands in horror and state that the educators are not only forcing these people as undergraduates to take a disproportionate part of their work in education, but they are also forcing them to take education for their master's degree. Many of these teachers would have liked to have taken their graduate work, or a major part of it, in science. Where can they get assurance by a science department in a college of Arts and Science at the beginning of their graduate work that they can obtain a suitable sequence of courses in science, sufficient in number, given at suitable times, and without

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[3] Committee Report by Harry A. Cunningham, chairman, in the Annual Report of Ohio Academy of Science. *The Ohio Journal of Science*, 58: 243, July, 1957.

prohibitive pre-requisites to give them reasonable assurance of emerging at the end with a master's degree?

Many of the graduate courses taken by research scientists are not suitable as graduate training for teachers—particularly grade teachers. Science departments in colleges of Arts and Sciences are, because of their past traditions concerning the desirable nature of graduate science courses, having difficulty in many instances in adjusting their offerings to meet this teacher need. This adjustment seems easier in biology than in physical science. We, in our Department of Biology, are, it would appear, being fairly successful in so adjusting our courses.

To the writer, it seems entirely reasonable and justifiable to work out a physical science course of graduate caliber with the minimum of pre-requisites that would give many of the early history making scientific experiments of the past, show the successes and failures of the early scientists in the use of the elements and safeguards of the scientific method and make an effort to look out from the interior of the science field into the various related areas in philosophy, history, politics, and religion to such problems as population numbers, race, health, and conservation. I fear that to most of my friends in physics and chemistry, such a proposal would seem scandalous. On this problem compromise seems in most cases impossible.

Most of the same problems that have been discussed above are also facing the high school science teacher. He, however, is getting help from all quarters. The government, science societies, private science and commercial agencies, and hundreds of individual scientists are helping. Dr. Mayor, in a little booklet entitled "A Study on the Use of Science Counselors," outlines the pilot studies in this area that have been made at the University of Nebraska, the University of Oregon, Penn State University, and the University of Texas.[4]

Science is a relatively new subject in both the elementary and high school curriculum. We may say that it is still in its formative stage in both schools. Science is particularly new in the elementary school and as we have noted above, many of the problems of teacher training result from the newness. From a subject of little or no recognition in the elementary school in 1900, science is now taking its place as a real part of the elementary curriculum. At the beginning its content was almost entirely biological nature study. At this very early period, in many cases but not all, science of animals and plants was mixed with personification, fairy tales and teleology. Another possible reason for the slowness in the introduction of physical science was the belief at that time that it was impossible and undesirable to try to

[4] John R. Mayor, Chairman of Staff, *Study on the Use of Science Counselors*, September, 1956, pp. 1–14

teach science principles below the high school. More and more physical science has been introduced until at the present more than half of the science content for the elementary school is physical science. In the meantime the name of this course in the elementary school has been changed from Nature Study to Science. The writer has sat through many stirring meetings in which tensions ran high as the matter was argued by the "old guard" for "Nature Study" represented valiantly by Dr. E. Laurence Palmer from Cornell and the idea for "Science" by the young "upstarts," Powers, Craig, Robertson, Curtis, and Downing from Columbia, Michigan, and Chicago.

Changes have also taken place in high school science. Before the year, 1900, the high school science subjects were physical geography, physiology, botany, zoology, physics, and chemistry. Around the beginning of this century changes rapidly came about. Physical geography, physiology, botany, and zoology rapidly disappeared from the scene. General science, general biology along with agriculture and home economics appeared.

A little before this change in subjects and undoubtedly one of the causal factors of the change was the rapid increase in high school population. Downing reports that "the total high school enrollment from 1890 to 1920 increased 854 per cent while the growth in population was only sixty-nine per cent."[5]

At this time the American people began to realize the economic responsibilities involved in their commitments to extend high school education to everyone. This increase in cost was one causal factor for the studies that began about 1920 relative to the importance of lecture-demonstration versus individual laboratory work. School people also realized that they had in their schools a great variety of young people that differed greatly in ability, interests, attitudes, and appreciations. These great individual differences were certainly one causal factor in bringing about the changes in the type of science courses.

Another factor that certainly influenced the change in the nature of subject matter was the rise of a different educational philosophy. There was a change from the old world philosophy of Plato that stood for a fixed body of subject matter to be learned by all the students to the present dominant philosophy of Dewey and Kilpatrick. This philosophy favors no set course of dictated subject matter, but rather favors a set of things to be done, problems to be solved, experiences to be encountered, and tends to assume that in this process of experiencing, enough content will be learned. The former philosophy is supposed to emphasize verbalism, the latter, experience. This idea

[5] Elliot R. Downing, *Teaching Science in the Schools*, 1925, p. 25.

of experience-getting and problem solving is very well presented in a recent article by Laura Zerbes.[6]

In the development of one of the first subject matter materials in general science, some of the specialized scientists helped. Dr. R. A. Millikan was one of these scientists. He very soon, however, saw his error. In an article in SCHOOL SCIENCE AND MATHEMATICS he says, "I was intimately associated with the initiation of the General Science movement—for which I hope God may some time forgive me—so that I have had to look quite carefully into the teaching of all the secondary school sciences . . . its elements (science instruction) are simple and definite; and the mere statement of these elements at once points the way at least to the next steps in the solution . . . the successful technique of teaching high school physics, at least, and I think also of other high school sciences, is now pretty well known . . . for the last fifty years those who have been actually teaching secondary school physics have been working out by trial and error a successful technique of that teaching, and there is now large agreement upon it."[7]

This article by Millikan was answered the next year by Dr. E. R. Downing as follows: "But that the elements in the problem of secondary school science 'are simple and definite and that the mere statement of these elements at once point the way at least to the next steps in their solution' seems to me an optimism born of ignorance. His statement that the successful technique of teaching high school physics and also other high school sciences is now pretty well known, a technique which he claims has been worked out by trial and error is far from the truth. If one had made fifty years ago a similar statement in regard to medicine, namely that the technique of treating diseases had been thoroughly determined by the preceding centuries of the trial and error method, he certainly, in the light of the advances made in the last fifty years by the scientific method, could justly have been accused of rashness. The scientific study of the efficiency of the various types of procedure in the teaching of physics and other sciences has only just begun. The curious thing is that men who are supposed to be saturated with the scientific attitude of mind fail to see that the problems of teaching must be attacked in the same scientific way as the problems of the physical and biological sciences. Surely the trial and error method would not go far in settling the problems on which the present day physicist is at work. Nor can

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[6] Laura Zerbes, "Thoughts on the Education of Science Teachers for Today's Schools," *Science Education*, 42: 280–288, October, 1958.

[7] R. A. Millikan, "The Problem of Science Teaching in the Secondary Schools," SCHOOL SCIENCE AND MATHEMATICS, 25: 966–975, December, 1925.

we expect them to be more successful in settling the problems of teaching."[8]

These two philosophies have persisted in conflict from the time of the writing of these papers to the present. During most of this period the philosophy as represented by Downing has prevailed. Now the philosophy as represented by Millikan is gaining the ascendency.

It would seem to the writer that our friends in education have been so enraptured in the attainment of their ultimate social objectives, as set forth in the cardinal principles of secondary education, that they have almost forgotten to talk about content.[9] In a survey of the education literature made by the writer in the 1930's, it was found that the expressions content or subject matter were almost invariably preceded by the words mere or merely. The educators have played down too much the importance of subject matter.

Because of the great individual differences in high school students from the early part of this century, the methods of teaching as well as the types of subject matter, have been influenced. Because of the large number of students, much individual instruction has been impossible, but much attention has been given as to how best to care for individual differences and still teach students in large groups. We have this problem still with us.

More attention has been given in the past to the slow learner. Now we are greatly interested in the rapid learner. There seem to be two ways to meet this problem; one is enrichment, the other is acceleration. Evidently there are data that may be interpreted to support either point of view. What we think and do about this matter seems to be actually influenced more by our national needs. If the nation is in a depression and great numbers of people are out of work creating no great manpower need, enrichment will be emphasized. If more trained young people are needed in a hurry by the nation, acceleration will be favored. When acceleration is decided upon, there are two points of view to take concerning it. One is to get away from the idea of time to be spent and ground to be covered and give the fast learner different kinds of material of a more challenging nature that may permit him to enter college with advanced standing. The other is to stick to the idea of the time to be spent and ground to be covered. This is sometimes done by permitting the bright student to take an additional course in addition to all the regular required high school courses. The writer definitely favors the former plan for acceleration.

Teaching the ability to use the scientific method and the scientific attitudes has been an objective of science teaching for many years.

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[8] Elliot R. Downing, "The Problem of Science Teaching in the Secondary Schools—A Comment," SCHOOL SCIENCE AND MATHEMATICS, 26: 301–303, March, 1926.

[9] *Cardinal Principles of Secondary Education.* Bulletin, 1918, No. 35. Department of the Interior, pp. 5–32.

This objective has seemed especially appropriate for science teaching because pure science is studied by this method and the rather newly developed field of science education uses it in the study of problems in the field of science teaching. The appropriateness of this method for use either in the study of teaching problems or as an objective of science teaching has not universal approval. The situation today on this question is much the same as presented above in the quotations from Millikan and Downing with the exception that the aggressive attack is now being made on the scientific educators. The appropriateness of the use of this method as an objective of science teaching should now be re-examined.

Since a very small percent of the young people taught science by any one teacher in either the elementary or high school will ever become research scientists, these teachers must teach that the scientific method can and should be used in the solution of problems in other fields. Just what other fields are appropriate for its use? Possibly ninety percent of the people would not commit themselves as being in favor of using the method in all problematic situations. Dr. James Conant takes the point of view that it is inadvisable to use the scientific method as an objective.[10,11]

Finally, there is another part of our educational theory that, while usually assumed to be above question, needs re-examination. It would seem to be no accident that in recent years science teaching has emphasized big ideas or generalizations as objectives.

In the judgment of the writer these very large generalizations such as "space is vast," "time is long," "there are many inter-relationships in nature," etc., are so big, so vast, and so general as to be practically useless. It is impossible to apply them to practical problems because of their generality. A still further criticism may be made that the organization of a science course around principles tends to overemphasize deductive teaching. Such a plan leads, in too many cases, not to the induction of principles, but to the learning of principles and then giving a few illustrations of fact to support the principles after the statement of the principle is known.

The idea of inducing generalizations of smaller size stated as cause and effect relationships seems in many instances to have been forgotten. We seem also to have forgotten that introducing a unit of study in science through an abstract generalization is a most uninteresting approach from a young person's point of view.

At about the time I graduated from college there began to appear somewhere in the biology books, a little paragraph, sometimes in fine print, on a relatively new idea—The Organismal Theory. The idea

[10] James B. Conant, *On Understanding Science*, 1947, pp. 4–11.
[11] James B. Conant, *Education in a Divided World*, 1949, pp. 119–129.

quickly spread to psychology and to education. It must be admitted that ground for emphasis of this theory has been supported by experimental data from both biology and psychology. I read an article bearing on this theme back in 1938 and the main idea of the article has stuck in my thinking ever since. The article was in *Progressive Education*, Booklet No. 5, entitled "Contributions of the Basic Sciences to Education and Social Progress." This particular article was by Raymond H. Wheeler, University of Kansas, and was entitled "Some Psychological Laws of Social Progress."[12] The gist of this article was that we have had many periods in the past when the organismal idea prevailed. We had such periods in 1928, 1818, 1650, 1250, and in 350 B. C. At such periods Mr. Wheeler pointed out that deductive methods were used and dictatorships in one form or another prevailed. The idea prevailed that *the whole of anything is more than the sum of its parts and is so organized that it regulates the activities of the parts*. We are more likely to feel that at such times we in science are trying to get in step with the times, but it might very well be that society is trying to get in step with science.

Mr. Wheeler goes on to say that "If science is giving a certain picture of the world, then society is trying to live and exist and progress in terms of that same picture—without knowing it, perhaps . . . there is a direct correlation between the appearance in history of dictatorships and of certain types of scholarship in science. In other words, there is no such thing as a theory which is not a living, functioning thing in society at the same time that the theory appears." The idea in this case is that everything that exists plays a part in a plan, in an order, in a society. *The part has a role to play in a purposive plan. That purpose is the goal of the whole.* For many years the writer has taught a course in organic evolution. During this period it has been rather difficult to teach the subject without assuming that the evolution has a goal. It may very well be that our organismal theory has had more influence in world affairs than we have dreamed.

[12] Raymond H. Wheeler, "Some Psychological Laws of Social Progress," in *Contributions of the Basic Sciences to Education and Social Progress*, pp. 5–10.

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The Periodic Library*

An Aid to Understanding the Periodic Table

Herbert Bassow

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No high school chemistry course is complete without some consideration of the periodic table of the elements. Beginning students, lacking familiarity with these elements, often find it difficult to understand the organization of the commonly used "long form" table, and consequently never fully appreciate the "explanation" of this organization via the electron "shell" theory. Especially confusing to beginners is the placing of the transition metals, the blank space this leaves above them, and the location of the rare earths and actinides.

One way to attack this problem is by developing an analogous, albeit hypothetical, organization in an area more familiar to students. Based on the assumption that English literature and use of the library constitute such an area in most schools, the writer has found an analogy involving them to be of use as an introduction to the periodic table.[1]

The analogy takes the form of a list of books (Table 1) in which various subjects and authors are made to recur periodically throughout. These books must be arranged by the student in an empty bookcase (Fig. 1) so that, while the list's order is maintained—enabling it to become the "catalogue," all books of a given subject or author can

* Based on the Author's, "Here's How I Do It" Presentation at the 1959 N.S.T.A. Convention, Atlantic City, N. J., April 4, 1959.

[1] The originator of this analogy, as well as the extent to which it has previously been developed, are unknown to the author. Various texts (e.g., Holton-Roller, "Foundations of Modern Physical Science," Addison-Wesley, 1958, p. 418) do refer briefly to the idea.

be found in one vertical column—rather than scattered about the bookshelf.

TABLE 1

THE BOOKLIST*

No.	Author and/or Subject	No.	Author and/or Subject
1	Language of Science	39	Shakespeare, Tragedies, Volume II
2	Religion, Ancient	40	Austin, Pride and Prejudice
3	Language, English	41	Butler, Life and Habit
4	English Literature, Volume I	42	Conrad, Nostramo
5	Poetry, Burns	44	Hardy, Tess of the D'Urbervilles
6	Art, Gauguin	45	Huxley, Brave New World
7	Philosophy, Kant	46	James, Daisy Miller
8	Math, Arithmetic	47	Twain, Huckleberry Finn
9	Science, Biology	48	Wilde, Lady Windermere's Fan
10	Religion, Egyptian	49	Poetry, Arnold
11	Language, French	50	Art, Picasso
12	English Literature, Volume II	51	Philosophy, Locke
13	Poetry, Blake	52	Math, Trigonometry
14	Art, van Gogh	53	Science, Chemistry
15	Philosophy, Spinoza	54	Religion, Hinduism
16	Math, Geometry	55	Language, Russian
17	Science, Geology	56	English Literature, Volume V
18	Religion, Judaism	57–71	Shakespeare, Sonnets (15 separate volumes)
19	Language, German	72	Austin, Emma
20	English Literature, Volume III	73	Butler, Erewhon Revisited
21	Shakespeare, Tragedies, Volume I	74	Conrad, Lord Jim
22	Austin, Sense and Sensibility	75	Dickens, Pickwick Papers
23	Butler, The Way of All Flesh	76	Hardy, The Return of the Native
24	Conrad, Victory	77	Huxley, Antic Hay
25	Dickens, Oliver Twist	78	James, The Portrait of a Lady
26	Hardy, The Mayor of Casterbridge	79	Twain, Connecticut Yankee
27	Huxley, Point Counterpoint	80	Wilde, De Profundis
28	James, The Turn of the Screw	81	Poetry, Browning
29	Twain, Tom Sawyer	82	Art, Renoir
30	Wilde, The Picture of Dorian Gray	83	Philosophy, Mill
31	Poetry, Coleridge	84	Math, Calculus
32	Art, Rembrandt	86	Religion, Buddhism
33	Philosophy, Hume	88	English Literature, Volume VI
34	Math, Algebra	89–102	Shakespeare, Comedies (14 separate volumes)
35	Science, Astronomy		
36	Religion, Christianity		
37	Language, Spanish		
38	English Literature, Volume IV		

* This list is to become the "catalogue" of the periodic library.

Since no horizontal shelf can accommodate more than 18 books, the list must be broken in various places, and continued on the shelf below. If the "breaks" are made after each religion book, the resultant arrangement is shown in Figure 2. That this is the best possible beginning is evident from the positions of the language books, all occupying the extreme left-hand vertical column as shown in the

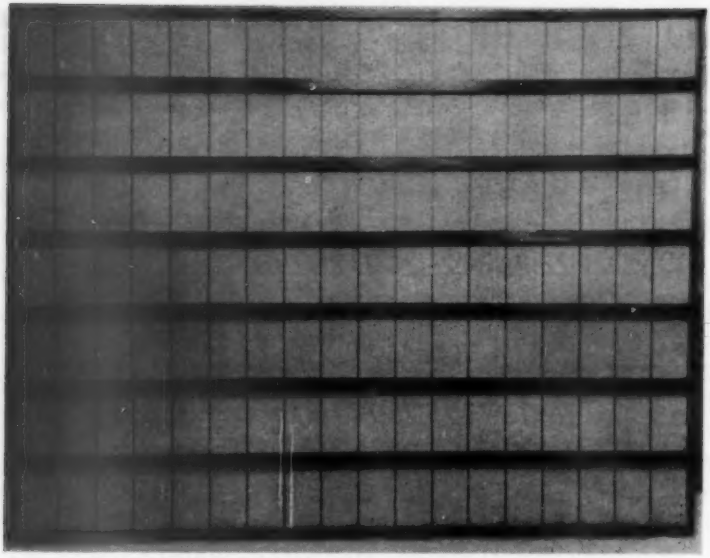

FIG. 1. The empty bookcase. Each horizontal shelf can accommodate a maximum of 18 books.

1 2
3 5 6 7 8 9 10
Poet. Art Phil. Math Sci. Relig.
11 13 14 15 16 17 18
Poet. Art Phil. Math Sci. Relig.
19 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Dick. Hamil. Hux. Jam. Twa. Wild. Poet. Art Phil. Math Sci. Relig.
37 39 40 41 42 44 45 46 47 48 49 50 51 52 53 54
Hamil. Hux. Jam. Twa. Wild. Poet. Art Phil. Math Sci. Relig.
73 74 75 76 77 78 79 80 81 82 83 84 86
Dick. Hamil. Hux. Jam. Twa. Wild. Poet. Art Phil. Math Relig.

FIG. 2. The result of filling the bookcase by breaking the list after each Religion book. Note that while all Language books are vertically aligned, others are not.

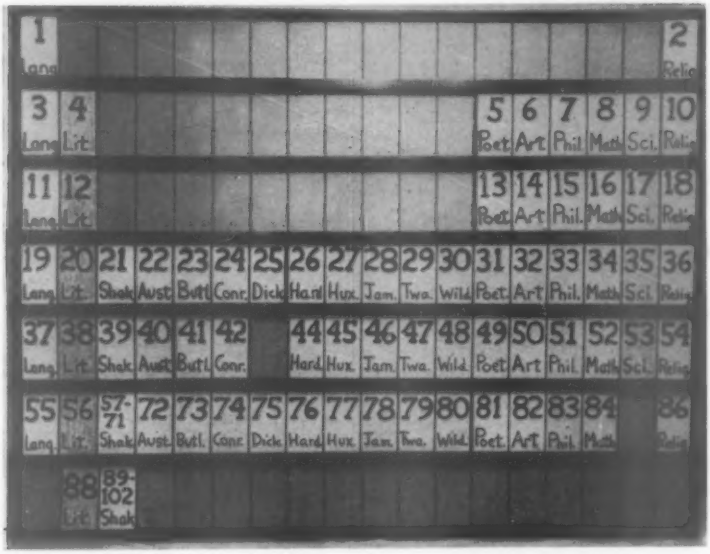
1 Lang
2 Relig
3 Lang 4 Lit
5 Poet 6 Art 7 Phil 8 Math 9 Sci. 10 Relig
11 Lang 12 Lit
13 Poet 14 Art 15 Phil. 16 Math 17 Sci. 18 Relig
19 Lang 20 Lit. 21 Shak 22 Aust. 23 Butl. 24 Conr. 25 Dick 26 Hard. 27 Hux. 28 Jam. 29 Twa. 30 Wild. 31 Poet. 32 Art 33 Phil. 34 Math 35 Sci. 36 Relig
37 Lang 38 Lit. 39 Shak 40 Aust. 41 Butl. 42 Conr. 44 Hard. 45 Hux. 46 Jam. 47 Twa. 48 Wild. 49 Poet 50 Art 51 Phil. 52 Math 53 Sci. 54 Relig
55 Lang 56 Lit. 57-71 Shak 72 Aust. 73 Butl. 74 Conr. 75 Dick 76 Hard. 77 Hux. 78 Jam. 79 Twa. 80 Wild. 81 Poet. 82 Art 83 Phil. 84 Math 86 Relig
88 Lit. 89-102 Shak

FIG. 3. The result of shifting certain volumes from their positions in figure 2 until every related book is vertically aligned. This is the periodic library.

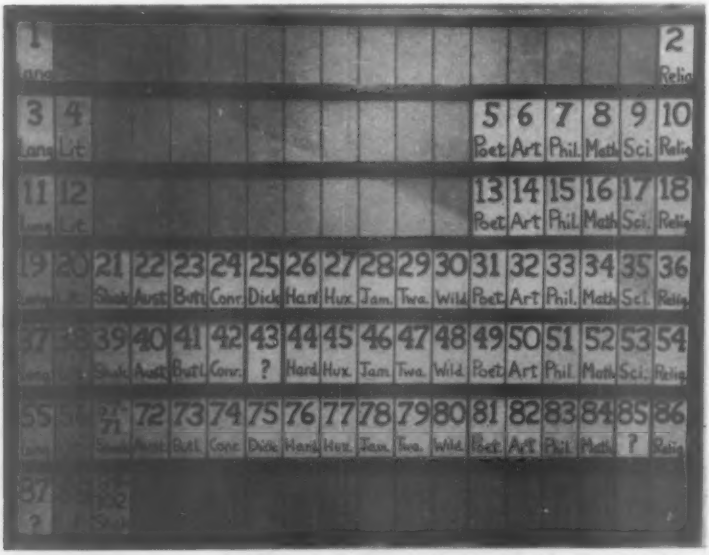
2
3 4
5 6 7 8 9 10
Poet Art Phil. Math Sci.
11 12
13 14 15 16 17 18
Poet Art Phil. Math Sci.
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Shak Aust. Butl. Conr. Dick Hard. Hux. Jam. Twa. Wild. Poet. Art Phil. Math Sci.
39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54
? Hard. Hux. Jam. Twa. Wild. Poet Art Phil. Math Sci.
72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
Aust. Butl. Conr. Dick Hard. Hux. Jam. Twa. Wild. Poet Art Phil. Math ? Relig
37

FIG. 4. Predictability. If the books missing from Figure 3 are ever found, their titles could be predicted from their places in the library. Thus book 43 would be by Dickens, book 85 on science, and book 87 on language.

figure. Now it is a simple matter to shift certain volumes horizontally, while maintaining the list's numerical order, until every related book has its own vertical column. The result of this best possible organization, the so-called "periodic library," is shown in Figure 3.

If the books become elements, their numbers are atomic numbers, and the library becomes the periodic table. The many advantages of the long form's organization are therefore comparable to those of the library. Considering the volumes in their order on the list, the following analogies apply:

Book 1, representing element 1, could be placed in either the "language" or "science" column, just as hydrogen is listed in group I or group VII.

Books 21–30, and those vertically below, represent the transition metals. They follow English lit. both numerically and sensibly, for they belong in the English lit. section of the library, and nowhere else. Since no first or second shelf books are related, the space above them is empty. The place of the transition metals, and the space above them will now be apparent, for the same reasoning applies.

The fifteen separate Shakespeare Sonnets (Books 57–71), and the fourteen separate Comedies (Books 89–102), can only occupy one space each without disrupting the rest of the library, so that they would have to be placed on the "floor below" the bookcase. The rare earths and actinides must similarly be listed below the table, since, organizationally, they belong in spaces 57 and 86 respectively.

A final analogy is predictability. The student can immediately see that book 43, if it is ever found, must be a Dickens; Book 85, similarly, will be on science; and Book 87, on language (Fig. 4). Thus Mendeleeff's prediction of the properties of Germanium (his eka-Silicon) becomes less mysterious, while the power of the table becomes more and more apparent.

Once organization of the table is understood, the student is ready to wrestle with theoretical explanations. For certainly the fact that ALL volumes can be vertically aligned, in addition to the pre-arranged language one (corresponding to the alkali metals), is much more than coincidence. The fact of this remarkable order, in library or table, implies a "master plan" which would explain the order, and which further study might reveal. The time is therefore at hand to begin atomic structure studies, which will lead, eventually, back to the periodic table.

CAMERA-MICROSCOPE HAS MANY USES

Cancer research and oil geology have at least this much in common. Both fields are making valuable use of a new push-button type combination microscope and camera. The instrument is being used daily in a Houston hospital to study cancer cells, and geologists are using it to study the fine details of earth formations and fossils. Magnifying up to 2,500 diameters, the microscope can be used with transmitted, reflected, polarized or fluorescent light.

Multiplication Socialized

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There are some logical aspects of multiplication which handicap careful thinkers in teaching arithmetic. The narrow definition of the process makes the thinking unnecessarily difficult in applying multiplication to many social situations in which it is needed. A broader definition which shows its basic and first meaning and then its enlarged meaning as society places greater and greater demands upon it, would greatly simplify our analyses, and liberate the process for greater social usefulness.

1. The Problem Is Concerned with the Meaning of Multiplication

The following illustrations present in specific form the social setting for multiplication and its common usage.

1.1) The multiplier is abstract and is an integer, the first and basic meaning.

a. $3 \times 5 = 15$, means $5+5+5=15$
b. 3×5 ft. $= 15$ ft., means 5 ft. $+5$ ft. $+5$ ft. $= 15$ ft.
c. $200 \times \$320 = \$64{,}000$, means $\$320+\$320 \ldots$ (200 of them)

Definition: Multiplication is a short process for finding the sum of a number of equal addends. The multiplier indicates the number of times the multiplicand is used as an addend; therefore, the multiplier must always be abstract and an integer.

1.2) The multiplier is abstract, but a fraction or a decimal, the first extension.

a. $\frac{3}{4} \times 12 = \frac{3}{4}$ of $12 = 9$
b. $\frac{3}{4} \times 12$ ft. $= \frac{3}{4}$ of 12 ft. $= 9$ ft.
c. $2\frac{1}{2} \times \$6.75 = \$6.75 + \$6.75 +$ what? $\frac{1}{2}$ of \$6.75
d. 6% of $\$100 = .06 \times \$100 = \$6$.

The multipliers $\frac{3}{4}$, $2\frac{1}{2}$, and .06 do not indicate the number of times the multiplicand is used as an addend, yet they do reveal common social usage. Here the multiplier uses a part of the other factor, and $\frac{1}{4} \times 12$ ft. is like 12 ft. $\div 4$: that is, 12 ft. divided into 4 parts.

1.3) Having the multiplier concrete, common social usage.

a. Area of a rectangle equals base times height, or $A = bh$. Find A if $b = 5$ ft. and $h = 3$ ft. $A = 5$ ft. $\times 3$ ft. $= 15$ sq. ft.
b. Volume of a rectangular solid equals the area of the base times the height. $V = Bh$.
$B = 15$ sq. ft., $h = 4$ ft., find volume.
$V = 15$ sq. ft. $\times 4$ ft. $= 60$ cu. ft.

c. $A=\pi r^2$. Find A when $r=10$ in.
$A=3.142\times(10 \text{ in.})^2=314.2$ sq. in.

d. Change 120 in. to ft.
120 in. ÷ 12 in. = 10. Therefore 120 in. = 10 ft. (usual thinking)

$$120 \text{ in.} = 120 \text{ in.} \times \frac{1 \text{ ft.}}{12 \text{ in.}} = 10 \text{ ft.}$$ (using a "*unity transformer*")

e. $D=Vt$. Find D when $V=40$ mph and $t=2\frac{1}{2}$ hr. (use in physics)

$$D=40 \text{ mph} \times 2\tfrac{1}{2} \text{ hr.} = \frac{40 \text{ mi.}}{1 \text{ hr.}} \times 2\tfrac{1}{2} \text{ hr.} = 100 \text{ mi.}$$

f. $V=at$. Find V when $a=2$ ft. per min. per min., or $a=2$ ft./min.^{2}, and $t=5$ min.

$$V=2 \text{ ft. per min. per min.} \times 5 \text{ min.} = \frac{2 \text{ ft.}}{1 (\text{min.})^2} \times 5 \text{ min.} = \frac{10 \text{ ft.}}{1 \text{ min.}}$$

or 10 ft./min. or 10 ft. per min., the velocity.

g. 100 lb. × 10 ft. = 1000 ft. lb. (use in physics)
h. 20 men × 10 hr. = 200 man-hours (use in industry)

Operations such as those in illustrations under 1.1 and 1.2 are accepted, but those in number 1.3 are not generally accepted by mathematicians even though very useful. They are made unnecessarily difficult to think through logically because of the very limiting definition for multiplication in 1.1 preceding.

1.4) Status and consequences of the limiting definition.

A study of fifteen modern series of mathematics textbooks for grades seven and eight reveals that 9 of the 15, or 60%, have accepted the broader definition in the wording of the rules for areas and volumes, but only one of those nine actually uses an expression such as, "5 ft. × 3 ft. = 15 sq. ft." Their rule is, "Area of a rectangle equals length times width, or base times height."

Six of the fifteen, published in 1956 or earlier, use the phrasing, "The number of units of area in a rectangle is equal to the product of the number of units of length and the number of units of width." Usually the rule is followed by or includes in the rule the statement, "The length and width must be expressed in like units and the area will be in corresponding units." All fifteen of these books have very recent copyright dates; those dated 1957 or 1958 are in the first group of nine. A similar study thirteen years ago revealed about 10% implying the broader definition of multiply which permits both factors to be concrete. Seemingly there is a trend toward this socializing of the process of multiplication and freeing it from the logical handicaps with which it now struggles.

Furthermore, the present definition has the inescapable result logically that all operations in arithmetic must really be done with

abstract numbers, not quantities. If the formula, $A=bh$, is given the traditional interpretation, none of the letters can be quantities, each must be the "number" of units in the area, base, or height. The b cannot be an abstract 5, and the h, 3 sq. ft. Similarly in $A=\pi r^2$, one r cannot be abstract and the other concrete, such as one $r=5$ and the other $r=5$ sq. ft. The logical consequence must be that no addition, subtraction, multiplication, or division can be done with concrete materials. It must all be done with abstract numbers, and later the proper units attached. One new book with the older definition gave the following, "$5\times4=20$ sq. ft." This is clearly incorrect. We must say "$5\times4=20$, and therefore, the area is 20 sq. ft.," or "5 ft.$\times$4 ft. $=20$ sq. ft." or "5×4 sq. ft. $=20$ sq. ft."

For meaningful teaching we often use concrete materials. It is physically possible to add: 6 ft.$+2$ ft., to subtract: 6 ft.-2 ft., to divide: 6 ft.$\div2$ ft. or 6 ft.$\div2$, and to multiply: 6 ft. by 2, or 6 ft. by 2 ft. These processes can all be presented concretely and meaningfully yet logically arithmeticians cannot accept any of these operations with quantities unless they accept them for multiplication. For example, the formula for the total area of a cylinder is:

$$A=2\pi r^2+2\pi rh=2\pi r(r+h).$$

Either all letters or none can represent actual lengths. There can logically be no middle ground. All operations must be done with numbers only, none with quantities; or, our definitions must be liberalized and quantities as addends or factors legalized logically.[1,2,3]

2. Applications Needed and Widely Used

In algebra and in physics this problem has been solved by the acceptance of a broader definition for multiplication. In fact in the multiplication of sets the definition is so completely changed that it is hardly recognizable as multiplication.

2.1) In algebra, letters may represent numbers, or quantities such as distance, weight, and time. The following operations are commonplace and necessary.

Algebraic operations allowed	*Arithmetical operations not allowed*
a. $5X\cdot3X=15X^2$	a. 5 ft.$\times$3 ft. $=15$ sq. ft.
b. $15X^2\cdot4X=60X^3$	b. 15 sq. ft.$\times$4 ft. $=60$ cu. ft.
c. $5X\cdot3Y=15XY$	c. 5 men$\times$3 hr. $=15$ man-hours
d. $\frac{5Y}{X}\cdot4X=20Y$	d. $\frac{50\text{ mi.}}{1\text{ hr.}}\cdot4\text{ hr.}=200\text{ mi.}$
e. $15Y\cdot\frac{Z}{5Y}=3Z$	e. $120\text{ in.}\cdot\frac{1\text{ ft.}}{12\text{ in.}}=10\text{ ft.}$

[1] Buckingham: *Elem. Arith., Its Meaning and Practice*, Ginn, 1947, p. 435.
[2] Larsen: *Arithmetic for College*, Macmillan, 1958, p. 188.
[3] Butler & Wren: *Teaching Secondary Mathematics*, McGraw-Hill, 1951, p. 310

f. $\frac{8X}{Y^2} \cdot 6Y = \frac{48X}{Y} = 48\frac{X}{Y}$ f. $\frac{8 \text{ ft.}}{\text{sec.}^2} \cdot 6 \text{ sec.} = \frac{48 \text{ ft.}}{\text{sec.}} = 48 \text{ ft per sec.}$

2.2) Physics is handicapped by the mathematician's narrow definition of multiplication. To avoid conflict, he calls such multiplication, "dimensional analysis." Physicists in general find that less confusion and error will be involved if multiplication can be accepted in which both factors may be concrete. Dr. Harvey White in his television course in College Physics via "Continental Classroom," uses this concept frequently, naturally and very effectively.

a. A foot-pound is defined as the unit of measure for work. One foot-pound is the amount of work necessary to raise 1 pound a distance of 1 foot against gravity. The work required to lift 5 lb. to a height of 10 ft. = 5 lb. × 10 ft. = 50 foot-pounds.[4]

b. Handling the unit names like letters in algebra or like numbers makes for less error and greater simplicity. Note its use in the formulas: $S = Vt$ and $S = \frac{1}{2}at^2$.

$$S = Vt = \frac{20 \text{ ft.}}{1 \text{ sec.}} \times 10 \text{ sec.} = 200 \text{ ft.}$$ [5]

Dividing out the unit 1 sec., like one would divide or "cancel" out any other factor, works perfectly.

c. $S = \frac{1}{2}at^2 = \frac{1}{2} \times \frac{4 \text{ ft.}}{\text{sec.}^2} \times (5 \text{ sec.})^2 = \frac{2 \text{ ft.}}{\text{sec.}^2} \times 25 \text{ sec.}^2 = 50 \text{ ft.}$ [5]

d. $V = at = \frac{50 \text{ ft.}}{1 \text{ (sec.)}^2} \times 4 \text{ sec.} = \frac{200 \text{ ft.}}{1 \text{ sec.}} = 200 \text{ ft./sec.} = 200 \text{ feet per second.}$

e. 22 ft. per sec. = ? miles per hour.

$$\frac{22 \text{ ft.}}{1 \text{ sec.}} = \frac{22 \text{ ft.}}{1 \text{ sec.}} \times \frac{3600 \text{ sec.}}{1 \text{ hr.}} \times \frac{1 \text{ mi.}}{5280 \text{ ft.}} = \frac{22 \times 3600 \times 1 \text{ mi.}}{5280 \times 1 \text{ hr.}} = 15 \frac{\text{mi.}}{\text{hr.}} \text{ or 15 mph.}$$

The "transformers,"

$$\frac{3600 \text{ sec.}}{1 \text{ hr.}} \text{ and } \frac{1 \text{ mi.}}{5280 \text{ ft.}},$$

are both fractions with terms equal; therefore, multiplying by them is like multiplying by unity. They may be called "*unity transformers.*" They transform feet per second to miles per hour through cancellation by division of the units feet and seconds and replacing them by miles and hours.

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[4] White, Harvey: *Modern College Physics*, Van Nostrand 1956, p. 125.
[5] Elliot & Wilcox: *Physics*, Macmillan, 1957, p. 136.

f. $V^2=\left(50\ \frac{\text{ft.}}{\text{sec.}}\right)^2+2\times 32\ \frac{\text{ft.}}{\text{sec.}^2}\times 200\ \text{ft.}=2500\ \frac{\text{ft.}^2}{\text{sec.}^2}+12800\ \frac{\text{ft.}^2}{\text{sec.}^2}$

$$=15300\ \frac{\text{ft.}^2}{\text{sec.}^2}.$$

Then $V=123.7\ \frac{\text{ft.}}{\text{sec.}}$.[6]

g. The principle of "moments," the product of the force and its distance from the fulcrum, provides another usage for concrete quantities as factors.[7]

h. Torque is the product of force times lever arm.

$$L=F\times r=5\text{ newtons}\times 3\text{ meters}=15\text{ newton meters.}$$[8]

2.3) Uses in business and industry.

a. Working time on a construction job often requires man-hours.

If 10 men work 8 hr. each, then the time, is 10 men$\times$8 hours or 80 man-hours. If the 10 men had each worked 8 days, the chargeable time would be 10 men$\times$8 days$=$80 man-days. Find the charge for 80 man-hours at \$2. per man-hour.

$$C=80\text{ man-hours}\times\$2/\text{man-hour}=80\text{ man-hours}\times\frac{\$2.00}{1\text{ man-hr.}}=\$160.$$

b. Any price is really a rate or ratio. e.g. With steak at \$1.25 per pound, what would 4 lb. of steak cost?

$$4\text{ lb.}\times\frac{\$1.25}{1\text{ lb.}}=\$5.000,\text{ or cost}=\text{amount times price.}$$

Without this technique the thinking takes the following form. "4 lb.$=$4 times 1 lb., therefore will cost 4 times as much as 1 lb. Then $4\times\$1.25=\$5.00$, the cost of 4 lb."

c. Water for irrigation is measured in acre-feet. Thus $80A\times.5$ ft.$=$40 acre-feet of water. Also $80A\times 6$ in.$=$480 acre-inches.

$$480\text{A. in.}\times\frac{1\text{ ft.}}{12\text{ in.}}=40\text{ A. ft.}$$

3. The Solution

The solution involves recognizing that multiplication like subtraction and division can have more than its first simple basic meaning. Subtraction sometimes means "take-away," often only "regrouping," and at other times "difference" or "how much more or less." Division may mean successive subtraction, partition, or ratio; at least these three quite different uses, even though the first one, measurement or successive subtraction is basic.

Similarly, the first use of multiplication must be as a short cut for

[6] White, *op. cit.*, p. 35.
[7] Elliot & Wilcox, *op. cit.*, p. 119 and White, *op. cit.*, p. 143.
[8] White, *op. cit.*, p. 153.

adding a number of like addends. Then along comes the need, not only for $6\times\frac{2}{3}$ yd. which means $\frac{2}{3}$ yd.$+\frac{2}{3}$ yd.$+\frac{2}{3}$ yd.$+\frac{2}{3}$ yd.$+\frac{2}{3}$ yd$+\frac{2}{3}$ yd., but also for $\frac{2}{3}\times 6$ yd., and this cannot mean 6 yd. taken $\frac{2}{3}$ of a time as an addend. $\frac{2}{3}\times 6$ yd. is related to $\frac{1}{3}\times 6$ yd. and this to $\frac{1}{3}$ of 6 yd. and this to 6 yd. $\div 3$. Therefore, $\frac{2}{3}$ as a multiplier means 2 is a multiplier and 3 is a divisor or

$$2/3\times 6=\frac{2\times 6}{3}=4.$$

Thus, a fractional multiplier must mean that the numerator is a multiplier and the denominator is a divisor.

A *concrete multiplier* is not so easily defined. The definition comes possibly in the unit used. How can multiplication be defined so that we can safely use such sentences as: 6 ft.$\times$5 ft.$=$30 sq. ft., or 6 acres$\times$.5 ft.$=$3.0 acre-feet, or

$$5 \text{ hr.}\times\frac{40 \text{ mi.}}{\text{hr.}}=200 \text{ mi.}$$

In a stimulating section, "New Measure for Old," Robert Swain[9] suggests an answer to the problem. He distinguishes between natural or "basic" measures, such as distance, time, and weight; and man-made or "derived" measures which are derived by multiplication or division from basic measures. These "derived" measures may include area and volume; speed and acceleration; foot-pounds, ton-miles, man-hours, and acre-feet; radio frequencies; birth or death rates; price per pound, per dozen, per yard, per hour, per month, etc. Thus the unit of area may be 1 sq. ft. or 1 sq. cm. and defined as 1 ft.$\times$1 ft., or 1 cm.$\times$1 cm. to distinguish it from addition or subtraction of these measures. The unit of speed may be mph or fps and defined as d/t. Then

$$tr=t\times\frac{d}{t}=d.$$

The basic units which form part of these derived units, as well as the derived units, should be dealt with like numbers or quantities just as

$$a^2,\ ab,\ \text{or}\ \frac{a}{b}$$

are in algebra. Since by definition 1 ft.$\times$1 ft.$=$1 sq. ft., then 6 ft.$\times$1 ft.$=$6 sq. ft. and also 6 ft.$\times$5 ft.$=$30 sq. ft. by the usual demonstration. Furthermore, 30 sq. ft. $\div$ 5 ft.$=$6 ft., just as $30a^2\div 5a=6a$.

[9] Swain, *Understanding Arithmetic*, Rinehart, 1957, p. 199.

Similarly,

$$R=\frac{D}{T}=\frac{200 \text{ mi.}}{5 \text{ hr.}}=\frac{40 \text{ mi.}}{1 \text{ hr.}}=40 \text{ mph. or } 40\frac{\text{mi.}}{\text{hr.}}.$$

Then

$$5 \text{ hr.}\times 40 \text{ mph}=5 \text{ hr.}\times\frac{40 \text{ mi.}}{1 \text{ hr.}}=200 \text{ mi.}$$

Another solution is to leave the term undefined, but to accept the fact that the operation must have whatever meaning is necessary in order to make these social uses logically possible. This seems to the author of this article the most sensible solution. Let multiplication beyond the first simple definition be technically undefined, but accept its meaning to be such that the powerful uses to which it may be put and is being put shall be accepted as legal and honorable and logical and mathematically respectable.

The chief value in such legitimizing of the process is a refinement of language and the elimination of error from ambiguity. For example, we have a rule that "the number of units in the area of a rectangle equals the product of the number of units in the length by the number of units in the width." Find the area of a rug runner that is 10 yd. long and 27 in. wide. The rule is ambiguous, because 270 is not the area in recognizable units. However, if the rule is: "Area = length times width"; then $A = 10$ yd. $\times 27$ in. $= 270$ yd. in., not 270 sq. yd. nor 270 sq. in. A yd.-in. is a possible unit, 1 yd. by 1 in., though not used. Using the shortened rule emphasizes that the units must be like units to get square units of any kind. Similarly in every illustration, the presence of the units in the multiplier and the multiplicand avoids error. Oranges at 25¢ per pound, per dozen, or per orange; or speed at 40 mph or 40 ft. per sec. are different "derived" units of measure. As soon as you omit the measuring unit to make multiplication possible, error is very likely to creep in. Using the whole measure avoids error in both thinking and computation.

Many mathematicians are very sensitive about this point. One superintendent, a former mathematics teacher, dismissed a teacher for writing on the chalk board, "6 ft. $\times$ 5 ft. = 30 sq. ft." Can we discuss this matter without emotion? May we exchange points of view concerning this problem by using SCHOOL SCIENCE AND MATHEMATICS as a vehicle? Can we help teachers and textbook writers to avoid the semantics and mental gymnastics which become necessary when we resist the pressure of this common usage? The physics teacher and textbook writer are greatly handicapped by their respect for the mathematician's opinion and are embarassed by having to omit

units in factors when they would like very much to use them.[10] Will physics teachers who read this article respond with their reactions? Would they like to say 200 g×20 cm.=4000 g-cm. without feeling apologetic to the mathematician?

[10] Elliot & Fisher, *op. cit.*, p. 120, 128, 146, 148, 150, 160, 161.

Addenda—The Status of Special Graduate Courses for the High School Chemistry Teacher

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An article in this *Journal*, Volume LVIII, Number 5, May, 1958, p. 404–9, identifies some changes in the traditional graduate teacher training programs throughout the United States. The trend seemingly is toward more satisfactory courses which are designed to meet the unique needs and the unusual undergraduate backgrounds that are characteristic of the average high school chemistry teacher.

The following programs are recent additions to those mentioned in the previous article.

American University, Washington, D. C., offers a Masters of Science in Science Teaching where up to twelve hours of junior and senior courses in chemistry may be taken for graduate credit.

Dominican College of San Rafael, San Rafael, California, now gives a Master of Arts in Biochemistry where one may take up to twelve hours of undergraduate work of upper division chemistry courses for graduate credit if they had not been taken previously.

Iowa State College, Ames, Iowa, gives a Masters of Science with a major in general science where some undergraduate courses may be counted.

Kansas State College, Manhattan, Kansas, gives a Masters degree in Physical Science Teaching where some undergraduate courses may be used for graduate credit, if they were not taken previously.

State University of South Dakota, Vermillion South Dakota, offers a Masters in Natural Science especially for those who do not have the equivalent of a professional undergraduate degree in chemistry and desire to improve their subject matter knowledge of chemistry.

University of Colorado, Boulder, Colorado, gives a Master of Basic Sciences where most of the work in the undergraduate upper division can count.

University of Idaho, Moscow, Idaho, gives a Masters of Natural Science with emphasis on the unique problems of the high school teacher.

University of North Dakota, Grand Forks, North Dakota, gives a Master of Science Teaching which makes it possible to cut across the individual disciplines rather than concentration in a single field.

Western State College of Colorado, Gunnison, Colorado, is giving special courses for the upgrading of high school science teachers that may be counted on a Master of Arts degree.

Deletions—University of Vermont, included in the original list, does not offer special courses.

Change—Antioch College gives a Masters of Science with special courses to distinguish it from the Masters of Sicience in Education.

Additions and changes in these listings will be made from time to time. Your cooperation is requested.

"LAMINATED" CERAMIC-METAL MATERIAL FOR NOSE CONES, JET ENGINES

"Laminated" ceramics and metals offer a new approach to the problem of making a heat-resistant material suitable for missile cones or jet engines of the future.

Attempts to combine ceramics and metals, strongly encouraged by the Air Force since World War II, have so far been concentrated on joining the individual particles of ceramic and metals, somewhat like mixing salt and pepper. The results have been generally unsatisfactory.

Under the new concept, molten metals and ceramics are first flame-sprayed in alternate thin layers on a rotating disk.

After cooling, the layer "cake" is crushed into small grains, with each grain retaining the laminated, or layered, ceramic-metal structure. The grains are then hotpressed in a graphite mold at temperatures of up to 2,200 degrees Fahrenheit.

The resultant ceramic-metal, or cermet, material resists both extreme heat and pressure. The mixture is considerably less brittle than ceramics, because the metal layer provides "slippage" for the ceramic layer.

Encouraging results have been attained by mixing 70% to 80% aluminum oxide for the ceramic layers with 20% to 30% stainless steel for the metal layers.

It is hoped that ultimately the laminated cermet mixture, besides its military potential, will have numerous civilian uses, especially for load-bearing structures exposed to very high temperatures.

YOUR PORTABLE RADIO MAY WARN OF RADIATION

The Atomic Energy Commission is working on development of a radiation detection instrument that will fit into transistor radios.

AEC Commissioner Dr. Willard F. Libby said in this way any person would be able to buy for a small extra sum protection in case of nuclear war. Such a device could also be used as a means of communications.

The aim is to develop an instrument sufficiently cheap so manufacturers can afford to put it into transistor radios by the millions. These could be advertised with a stamp of Government approval as a radiation monitor.

The Hawaiian Pineapple Industry

Glen W. Warner
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When the modern family sits down for breakfast young Pat experiences what would have been a banquet for her grandparents or great-grandparents of the late nineteenth century or the early twentieth. Then pasteurized milk was unknown to them; breakfast foods were few in both variety and quality; the fruit, if any was served, often consisted of dried apples or prunes packed in bulk. Today Pat starts with a small glass of fruit juice canned from the great orchards of Florida, California or more distant places. Her breakfast food may be any one of dozens developed at Niagara Falls or in Michigan's wonderful laboratories. The milk, or half-and-half if she needs it, pasteurized and homogenized, is taken from the paraffined paper container which definitely states that a fixed number of units of vitamin D has been added; or she may prefer Milnot, another compound developed only a few years ago. Her fruit may be an apple from the great orchards of Washington, then baked and immersed in syrup, or it may be half a papaya or a slice of pineapple from the garden fields of Hawaii three or four thousand miles from home but now only a few hours away.

Let us examine a little more closely this second greatest product[1] of our newest state, the great island chain stretching from the famous living vocanic island of Hawaii off to the northwest for over 1,500 miles, now known as the Mountain-top Isles. Here all plants have been imported by men or birds for these islands rose from the bottom of the Pacific in recent geological time and now stand as the highest mountains (measured from their base on the ocean floor) in the world. No one knows just when the first pineapples were grown here but the chief counselor of King Kamehameha I has recorded that he planted some in his garden in 1813. Some "Wild Kailua" were shipped to California about 1885 but the quality was very poor and the shipment did not pay. In 1882 an English Horticulturist, Capt. John Kidwell, brought some plants from Jamaica and started a cannery but did not succeed. However, his variety of plants, "Smooth Cheyenne," is the type grown on most of the land today. But the Pineapple Research Institute is constantly experimenting to produce better grades. By 1890 no successful crops had been grown. In that year D. D. Baldwin began his experiments at Haiku on the island of Maui, the second island of the group in size. In 1904 the first pack of 10,000 cans was produced by W. A. Baldwin of the Haiku Fruit Packing Company.

[1] Sugar cane is Hawaii's greatest crop.

In 1900 the first pineapples on Oahu were planted by James D. Dole, whose Hawaiian Pineapple Company sent out its first canned products in 1903, thus becoming the first successful pineapple exporter. This shipment consisted of only 1,893 cases or 45,432 cans. Today this same company prepares that many cans in twelve minutes.

How five of the islands, Maui, Oahu, Kauai, Molokai, and Lanai have fourteen plantations covering about 77,000 acres and yielding about $110,000,000 annually. Three canneries on each of the three largest of these islands process this fruit. Nearly eighteen million cans of pineapple slices, chunks and crushed fruit and over eleven million cans of juice are packed in one year by the nine companies. This is shipped abroad, most of it going to the United States mainland. Other pineapple products are bran from the shells for cattle food, citric acid, calcium citrate, alcohol and sugar.

Pineapple growing and processing is a year-round industry, furnishing employment to many of the inhabitants of the islands. About 10,000 people have steady employment, but through July, August and September some 12,000 more are needed. Many of these extra employees come from the high schools and colleges during summer

Dole Photo

Strips of mulch paper 32 inches wide are laid on plowed earth by three-row machines. Simultaneously soil fumigant is applied and, at times, fertilizer is introduced in two ribbons under the paper. Mulch paper looks like tar roofing paper. It discourages weed growth, holds moisture and heat in the soil. Paper is marked to show spots where pineapple slips are to be planted.

vacation. Housewives also add to the family income by working during the heavy canning season. Wages in the industry are favorable for all workers, going up to over two dollars per hour for the highest level.

In Hawaii pineapples do not produce the seed. Rather slips are taken from the peduncle at the base of the fruit or from the top of the fruit. The red soil is carefully prepared by plowing and harrowing to a garden fineness. Then a machine designed for the special purpose lays strips of mulch paper in long straight rows and fumigates the field. To date the planting is done as hand work. The workman punches a hole through the paper with a special trowel-like tool and inserts the plant. Fertilizer selected by chemical analysis of the soil is applied and weeding is done by chemical spraying. These fields are the most beautiful to be found anywhere for any type of crop. If farmers all over the United States could find some way to rid their corn fields of the many types of weeds that grow with the crop no doubt the grain yield would be much greater, cultivation would be a pleasanter task, and cornfields would always be beautiful to see.

It takes from 18 to 22 months after planting before the plants start to yield the ripe fruit. But it does not all ripen at one time. Men then follow the truck, selecting the ripe fruit and placing it in the fifty-foot long belt conveyor, which carries the fruit to the bin. These bins are then lifted onto trucks, each carrying about seven tons, to be hauled to the cannery or to boats if there is no cannery on the island on which they are raised. The plants usually bear one fruit in the center of a whorl of leaves and grow from three to four feet tall. After one crop is picked the stalks stand for about a year before another crop is produced. After this second crop has been harvested, the stalks are chopped to pieces and plowed under or used as a mulch for dry areas. The ground is then prepared and the next crop planted. Up to the present time there has been no rotation of crops but fertilizer is used extensively, based on thorough soil analysis done by the Pineapple Research Institute. This is an organization supported entirely by private funds contributed by all the pineapple growers.

Lanai, the sixth in size of the islands, is a most interesting community and an extensive plantation. It was purchased in 1922 by the Hawaiian Pineapple Company for $1,100,000 and more than one-seventh of its 90,200 acres is now under cultivation by this company. Lanai City, a town of about 2,500 inhabitants, is the home of the planatation workers. Many of them own their gardens and homes consisting of modern houses with plumbing, electricity, and often a family car. The city also has churches, theaters, a hospital, and service clubs, ball park, golf course, and other atheletic facilities. Radiotelephone connects them with the other islands and with the main-

land. A Territorial school provides education through high school. Much of the island not used for cultivation is planted to trees and grass. The water supply is the underground water from Maunalei Valley to the east. The water is pumped through a tunnel in the mountains and used both for the city and for irrigation in dry weather.

All the pineapples from this island are loaded on barges and taken to the great cannery on Oahu. Here it is possible to visit the canning plant and watch almost the entire process. A great battery of Ginaca machines removes the shells, clips off the ends, and cores the pineapples at the rate of over 100 a minute for each machine. The canning process is largely done by women in white caps and aprons and wearing long rubber gloves so that the fruit is not touched by bare hands. Nearly 5,000,000 cans have been packed in a single day. The big pineapple, a tank on top of the building, stands almost 200 feet above the street level and holds 100,000 gallons of water for washing and canning and for fire protection.

Other firms including Libby, McNeill & Libby and the California Packing Corporation control the production and processing on Molokai. Here the population leaped from a little over 1,000 in 1920 to over 6,000 by 1935 due to the pineapple industry. Hawaii Fruit Packers, Inc. and Hawaiian Canneries Company, Ltd. operate on Kauai. Baldwin Packers, Ltd. and Maui Pineapple Company, Ltd. are in control on Maui. Other firms also have large plantations and packing plants on Oahu and Kauai. Seventy per cent of the world's supply of pineapples is produced in these islands.

Like every other great industry vast quantities of supplies are needed to keep it going. "One big Honolulu firm produces enough cans of pineapple in one day to fill a 125-car freight train. This same cannery has twenty miles of cable and belting in use every day, and uses approximately three thousand gallons of paint each year. It has its own box factory, using enough paper every year to lay a five-foot strip from Honolulu to San Francisco, back to Honolulu, on to Tokyo and Manila, and back to Honolulu again. The entire Hawaiian industry turns out enough cans of pineapple products each year to outline the coastlines and borders of the United States five times. That's about seven hundred million cans."[2]

[2] *Pineapple in Hawaii*, a publication of the Department of Public Instruction, Territory of Hawaii.

COAL YIELDS GERMANIUM

Transistors for outer-space communication systems may use germanium extracted from the earth-bound coal beds of Kansas. A study of the germanium content of 20 Kansas coals by the State Geological Survey of the University of Kansas found that germanium content ranged from 0.0005% to 0.099%. The present main source of germanium for transistors is residues derived from the smelting of zinc ores.

Algebra of Complex Numbers

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In a recent paper with the above title, Warren Strickland has offered a proof for the following theorem.

Theorem: Suppose $\cdot$ is a relation (sic) between the terms of the ordered pairs of complex numbers such that if u is a complex number and v is a complex number, then $u \cdot v$ is a complex number. If each of u, v, w is a complex number, and x is a real number, then

$$\text{(i)}\quad (x, 0)\cdot u = xu$$

$$\text{(ii)}\quad u\cdot v = v\cdot u$$

$$\text{(iii)}\quad u\cdot(v+w) = u\cdot v + u\cdot w$$

$$\text{(iv)}\quad |u\cdot v| = |u|\,|v|$$

implies that if (x_1, y_1) is a complex number, and (x_2, y_2) is a complex number, then

$$(x_1, y_1)\cdot(x_2, y_2) = (x_1x_2 - y_1y_2,\ x_1y_2 + x_2y_1).$$

This statement is probably a theorem [and, as will be shown, the slightly weaker assertion, obtained by adjoining to the list of conditions the condition '*(ii′)* $(u\cdot v)\cdot w = u\cdot(v\cdot w)$', is certainly a theorem]. However, Mr. Strickland's purported proof is not valid.

In order to mark down the error, and to obtain a starting point for a valid proof, we recall that, as shown in the paper under discussion, it follows from the hypotheses of the purported theorem that

$$(1)\qquad (x_1, y_1)\cdot(x_2, y_2) = (x_1x_2, x_1y_2 + x_2y_1) + (0, y_1)\cdot(0, y_2).$$

Mr. Strickland proceeds to show that if

$$(2)\qquad (0, y_1)\cdot(0, y_2) = (z, w)$$

then, for each $y_1 > 0$, $w \leq y_1|(0, y_2)|$. From this he argues that since this inequality holds for *each* $y_1 > 0$ [and each $(0, y_2)$], it must follow that $w \leq 0$. Of course, this argument is valid only if w is independent of y_1 [or of y_2]. From (2) it would appear very unlikely that w *is* independent of y_1 [although, if the purported theorem is indeed a theorem, this is the case] but no attempt is made to establish this independence.

The weaker theorem previously referred to [whose hypothesis includes the assumption that $\cdot$ is an associative operation] can be proved as follows. Starting with (1), we make use of (i), (ii), and (ii′) to show that

$$(x_1, y_1)\cdot(x_2, y_2) = (x_1x_2, x_1y_2 + x_2y_1) + [y_1y_2][(0, 1)\cdot(0, 1)].$$

Now, supposing that

$$(0, 1)\cdot(0, 1)=(a, b),$$

we see that

$$(3)\qquad (x_1, y_1)\cdot(x_2, y_2)=(x_1x_2+y_1y_2a,\ x_1y_2+x_2y_1+y_1y_2b).$$

In particular, for each x and y,

$$(x, y)\cdot(x, y)=(x^2+y^2a,\ 2xy+y^2b).$$

Now, using (iv) [or its weaker consequence: $|u^2|=|u|^2$], we see that again for each x and y,

$$(x^2+y^2)^2=(x^2+ay^2)^2+(2xy+by^2)^2,$$

from which

$$(2a+2)x^2y^2+(a^2+b^2-1)y^4+4bxy^3=0.$$

But, if this is to hold for each x and y, $a=-1$ and $b=0$. So, substituting in (3), we see that

$$(x_1, y_1)\cdot(x_2, y_2)=(x_1x_2-y_1y_2,\ x_1y_2+x_2y_1).$$

Although this is a neat way of justifying the usual definition for the product of complex numbers, it is somewhat misleading. To see why this is the case, note that conditions (i), (ii), (ii′), and (iii) would be satisfied for each definition of multiplication obtainable from (3). [So, (3) is equivalent to (i), (ii), (ii′), and (iii).] The problem of deciding on a definition of multiplication for complex numbers reduces to that of deciding on values for a and b in (3), and this decision must result from further requirements in addition to (i), (ii), (ii′), and (iii). A natural requirement is that there be *some* "absolute value mapping" of the complex numbers on the real numbers such that (iv) is satisfied. Now, this will be the case whenever $b^2+4a<0$; one need only stipulate that, for each x and y,

$$(4)\qquad |(x, y)|=\sqrt{x^2+bxy-ay^2}.$$

This restricts the choice of a and b somewhat, but still leaves a wide range of choices, each of which would give a satisfactory definition of multiplication. In fact, it can be shown that one obtains isomorphic number fields for all choices of a and b such that

$$(5)\qquad b^2+4a<0.$$

We are consequently forced to make an arbitrary choice, and, clearly, the simplest forms of (3) and (4) are obtained [subject to (5)] for $a=-1$ and $b=0$.

We were led to the condition (5) because it ensured the existence

of an absolute value mapping satisfying condition (iv). A better motivation for (5) involves investigating the necessary and sufficient conditions that division by complex numbers other than (0, 0) be always possible. This is equivalent to requiring that each complex number except (0, 0) have a reciprocal. That is, that, for each $(x_1, y_1) \neq (0, 0)$, there exist real numbers x_2 and y_2 such that $(x_1, y_1) \cdot (x_2, y_2) = (1, 0)$. The condition we want is that under which the system:

$$x_1x_2 + ay_1y_2 = 1$$

$$y_1x_2 + (x_1 + by_1)y_2 = 0$$

has a real solution (x_2, y_2) for $(x_1, y_1) \neq (0, 0)$. And this condition turns out to be (5). As before, the simplest choices for a and b are -1 and 0, respectively.

GROUNDED PLUGS URGED FOR ELECTRICAL TOOLS

Laundry appliances, hand tools, and garden equipment will have three-wire plugs and three-wire cords in the "not too distant future," to ward off accidental electrocutions.

The three-pronged plug eliminates the chance that the neutral wire will be disconnected instead of the "hot" wire when a single pole switch is thrown. This, in turn, removes the possibility that an internal short circuit could make the appliance frame electrically "hot," and quite dangerous, when it is thought to be safe.

Safety is the sole reason for use of grounded receptacles in homes and for electrically operated tools.

It has been suggested that appliance manufacturers replace adapter cords and plugs with three-wire half-round grounding receptacles for permanent installation in an outlet box. (The adapter cords and plugs, by letting the three-pronged plug be attached to the regular two-holed outlet, defeat the purpose of the grounded receptacle.)

FUTURE HOUSES MAY CHANGE COLOR ON HOT DAYS

Some day houses may change color from a verdant green to a pale yellow as the hot summer sun beats down heavily from a cloudless sky.

This color change, effected through "automatic" chemistry, would help keep the house cool. The lighter color would reflect more of the sun's rays. In winter, the house would retain its dark color to absorb the sun's warm rays.

This possibility was suggested by Space Technology Laboratories, Inc., following development of a chameleon-like coating for satellites. Devised by Rudolf X. Meyer of the Laboratories' Physical Research Laboratory, the coating is designed to keep satellite temperatures relatively constant to prevent certain instrument failures.

The scientist found that about 35 substances have the "chameleon" ability. In the case of polymer compounds, automatic reversible transition from the "sol" state to the "gel" state accomplished the color change as temperature goes up.

The Science Teacher and Radiological Science

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In order to prepare students for adult life, the curriculum of today's schools must reflect the problems that today's teenagers will meet after high school. For some high school students the problem is a simple one: college. Therefore, our schools *must* provide a college-preparatory curriculum which will give college-bound students well-rounded training in the basic disciplines. For a second group, high school is terminal. These students need not only a sound, general education, but they also need a vocation that will enable them to take their places as respected, self-supporting citizens at the end of high school.

For both groups there is a common need. Students must be aware of the problems confronting all members of our society, whether they be farmers, priests, storekeepers, physicians, or members of any other profession. For example, the present traffic problem in the United States is an acute one. Insurance companies have statistics to show that driver training in our high schools has reduced the traffic accidents among those teenagers who took advantage of this training. This is but one example of how our secondary schools are helping to meet today's problems.

There are many other such problems in our society, and this article treats one that you, as a science teacher, can be especially effective in solving. It deals with the area of radiological science which is developing in our society.

What is the radiological problem that exists in our society? There are two parts to this problem:

1. The "hazards" that exist due to the industrial and research uses of radioactive isotopes.
2. The hazard that would exist in the event of an enemy thermonuclear attack.

With respect to the first part of the problem, the principal need in our society is *understanding*. Citizens need to know that when a person is exposed to a source of nuclear radiation (not including neutrons), the person is *not* radioactive. The citizenry should also know that the amount of damage to the human body depends upon the amount and type of radiation exposure, and in most cases the damage is negligible. A great deal of understanding is also necessary with regard to the uses of radioactive isotopes in industry, medicine, agriculture, and research. Our citizenry needs to understand that radiation hazard signs and shielding materials are precautionary

measures, just as the skull and crossed bones are on a bottle of tincture of iodine. Most persons know what electricity can do for them, but they also respect it. In today's nuclear age, the population needs the same respect for and knowledge of nuclear radiation that they presently have for electricity.

From the standpoint of the science curriculum, the implications of the foregoing are quite clear. The concepts of nuclear structure and nuclear radiation, as well as the vocabulary necessary to understand these concepts, should be taught to every student that passes through the American school system. There are many courses now in existence in our school system in which these concepts can be taught. However, if all the students in today's schools are to be reached, the students must all enroll in one or more science courses. Science-curriculum reorganization has been discussed by the author[1] as well as many others, and will not be discussed again here.

The second part of the problem is the radiological hazard that would exist in this country in the event of a massive nuclear attack. This is usually called the "fallout" problem.

The subject of nuclear weapons is one of an intuitive interest to people of high school age. The formation of fallout debris could be considered as a part of the unit on heat in a physical science or physics course. The distribution of fallout material is a "natural" for insertion in any unit on weather and/or meteorology. The effects of radiation on all forms of life is a topic which could be inserted in any biology course in a unit on disease. Further understanding, on the part of all citizens, is necessary as to what such an event would mean to this country. All persons should be aware that the radiological hazard must be measured before any type of rescue and/or survival action can be understaken. Such topics as radiation dose rate, lethal dose, mid-lethal dose, radiation sickness symptoms, radiological contamination and decontamination are concepts which should be familiar to all persons today.

The writer does not believe it necessary to point out to qualified science teachers in what science courses such topics as the foregoing should be placed. However, it should be pointed out that in the future proposals for laws regarding nuclear radiation and its control will probably be put before the voters. Each citizen has the responsibility to inform himself on the issue before casting his ballot. The future voters in this country need to be taught *now* the concepts of radiological defense so that they can be prepared to discharge their responsibilities as United States citizens. As evidence that the author's

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[1] Renner, J. W., Bray, L. R., & Powell, Wm., "Points and Counterpoint in Science Teaching," *The Science Teacher*, May, 1958, pp. 181–84.

hypothesis may come true, witness the present controversy regarding the testing of nuclear weapons.

There is much more content in the area of radiological science (peacetime or wartime) than can or *should* be included in all high school science courses. However, nuclear radiation detection and measuring instruments, biomedical aspects of radiation, and radiation dose and dose rate calculations would make suitable science club projects and topics for discussion. There is enough diversity in radiological defense to satisfy the scientific interests of the most diverse group.

In summary, the present-day science offerings need to teach the students an awareness of the radiological hazards around them (as well as the good that can be derived from them), an appreciation for this problem, and some courses of action in the case of necessity.

MAGNETIC DIP POLE DRIFTS NORTHWARD

The magnetic dip pole, that spot on the earth's surface where the south end of a freely suspended magnetic needle points directly downward, is drifting slowly northward.

Several determinations of the position of the north magnetic dip pole during the last ten years have been analyzed. It was concluded that the pole will be at latitude 74.8 degrees north and longitude 99.6 degrees west at the beginning of 1960.

This corresponds to a point north of the Canadian mainland between Prince of Wales Island and Bathurst Island. The dip pole is drifting in a northerly direction at a rate of about 55 miles every ten years, it is reported in Sky and Telescope, astronomical publication issued here.

SOLAR HEAT MAY RUN SPACESHIPS

Spaceships and satellites may use silicon solar cells as a "work horse power source." E. F. Case and G. Sweet, Jr. of General Electric told a meeting of the American Institute of Electrical Engineers that solar cells to convert the sun's energy into electrical energy could serve as a long-life secondary power source for space vehicles. The power system would include a solar collector to concentrate the sun's radiant energy, a converter to transform the heat energy into electricity, and a storage means to save the heat or electrical energy for use while the space vehicle is in the earth's shadow.

CLOCK TO CHECK EINSTEIN

An atomic clock, so accurate that it should neither gain nor lose one second in 1,000 years, soon may be put into orbit in a satellite to check Albert Einstein's theory of relativity. The 30-pound timepiece will look like an electron tube and will house a stream of ammonia molecules. The experiment is aimed at determining whether a clock ticking in a different gravitational field above the earth runs faster than a clock left on the earth's surface. This should be a very precise check on the effects of gravity on light. The satellite clock is being developed by Hughes Aircraft Company under a contract from the National Aeronautics and Space Administration.

Research on Problems in Reading Science*

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The Purpose

The purpose of this report is to summarize the findings of research studies dealing with problems in reading science and to suggest some of the implications of these investigations.

Methods Employed

A search was made through the literature to locate research studies dealing with problems related to reading science. While a great deal of research has been done in the area of reading in general, few studies dealing specifically with problems in reading science have been undertaken. Hence, all the published studies that were available in the literature were included in this investigation.

The studies that were located were then classified under the major headings to which they seemed to belong.

Studies Involving the Development of Scientific Vocabulary

Two published studies dealing with the problem of development of scientific vocabularies for use in textbooks for science were found. One of these by Curtis[1] is a monumental study that seeks answers to five questions:

1. Are the vocabularies found in textbooks of science actually too difficult for the pupils for whom the books are intended?
2. Is there some definite and readily determined level of vocabulary in present textbooks of science which marks a sharp increase in difficulty of comprehension by the pupils, and which, therefore, is the level at which simplification of vocabulary in such textbooks should begin?
3. Is the difficulty which pupils encounter in reading textbooks of science attributable, to any considerable extent, to non-scientific, and hence non-essential, vocabulary?
4. Do present textbooks of science provide adequately for the mastery of essential vocabulary through definition and repetition?
5. What are important terms which should be mastered in the various courses of science?

The data for the study were obtained from one hundred master's theses completed under the direction of the author.

In general, lists of words were obtained by examining the glossaries of textbooks for general science, biology, chemistry, and physics. The

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* A paper delivered at the Third Annual Conference of the International Reading Association, Milwaukee Auditorium, Milwaukee, Wisconsin, 9:00 A.M., Saturday, May 10, 1958.

[1] Curtis, Francis D., *Investigations of Vocabulary in Textbooks of Science for Secondary Schools.* Boston: Ginn and Company, 1938. Pp. viii+127.

word lists thus assembled were compared with the lists of words assembled by others such as Thorndike.

The words were then submitted to qualified teachers in order to determine their values for inclusion in the respective courses. From the data thus obtained, lists of essential and desirable words were developed. Curtis found that:

1. Both the technical and the non-technical vocabularies of textbooks of general science, biology, chemistry, and physics are too difficult for the pupils for whom the books are written.
2. There is insufficient provision in such textbooks of science for repetition of difficult scientific terms and non-technical words.
3. Too large a percentage of the difficult words found in such textbooks of of science are non-scientific or non-technical words.
4. Too small a percentage of the scientific terms that are introduced into such textbooks of science are defined.
5. Not infrequently the definitions of scientific terms fail to appear in the textbooks until the terms have been used more or less extensively in earlier parts of the books.

Mallinson[2] conducted a study, using techniques similar to those of Curtis, for the purpose of developing a scientific vocabulary for general physical science.

A list of words was compiled through the use of textbooks, courses of study (state, county and city), and theses dealing with the area of general physical science. The list was then submitted for evaluation to a jury of forty-four persons all of whom had written textbooks, or articles on general physical science, or who had helped develop courses of study in that area.

The result is a list of four hundred words considered to be essential vocabulary for general physical science plus two hundred words considered to be desirable vocabulary for general physical science.

The list of terms may well be of value to those developing curriculum materials for courses in general physical science.

Studies Involving the Determination of the Level of Reading Difficulty of Textbooks for Science

Mallinson and his co-workers[3,4,5,6,7,8,9,10] conducted a series of studies in which similar techniques were used to determine the levels of reading difficulty of textbooks for the areas of elementary science, junior-high-school science, general science, general physical science

[2] Mallinson, George Greisen, "The Development of a Vocabulary for General Physical Science." *The Twelfth Yearbook of the National Council on Measurements Used in Education, Part II*, a Report of the Meeting held in Cleveland, Ohio, April 1955, 6–8.

[3] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks for General Physical Science and Earth Science." SCHOOL SCIENCE AND MATHEMATICS, LIV (November 1954), 612–6.

[4] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks for General Science." *The School Review*, LX (February 1952), 94–8.

[5] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Some Recent Textbooks for Science." SCHOOL SCIENCE AND MATHEMATICS, LVII (May 1957), 364–6.

and earth science, high-school biology, high-school chemistry, and high-school physics.

Since an analysis of all of the text material in all the books was impractical, a modification of the Flesch formula was used in the investigations.

It was decided to select for analysis from each textbook one sample passage for each one hundred pages or fraction thereof, but not less than five passages from any one textbook.

The number of pages in each text was computed by counting from the first page designated by an arabic numeral to the last page of the last chapter. Pages on which were found chapter headings, supplementary activities, and questions were included in the count. The pages on which were found the indices, glossaries and tables of contents were excluded.

The number of pages thus computed in each textbook was then divided by the number of samples to be taken from the respective textbook. In this way each textbook was divided into sections of equal numbers of pages. A page was then selected from each of the sections by using the table of random numbers.

A one hundred word sample was taken from each page thus selected by counting from the first word of the first new paragraph on that page. If the page contained no reading material, the sample was taken from the next page that did. The legends under the illustrations on the pages thus selected were disregarded. These samples were then analyzed using the Flesch formula.

In general, the data obtained from these efforts seem to suggest that the following conclusions are valid:

1. The levels of reading difficulty of many textbooks in all areas of science are too advanced for the students for whom they are written.
2. The differences between the levels of reading difficulty of the easiest and most difficult textbooks in all areas of science are significant.
3. In some textbooks of science whose *average* level of reading difficulty seems satisfactory there are passages that would be difficult for some students in grade levels above that for which the book is intended.
4. There is a great deal of variation among the levels of reading difficulty of textbooks designed for the same field of science.
5. Earlier passages in textbooks of science are not likely to be less difficult than passages found later in the books.
6. Many textbooks of science contain non-technical words that could be replaced with easier synonyms.

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[6] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks for High-School Biology." *The American Biology Teacher*, XII (November 1950), 151–6.

[7] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks for High-School Chemistry." *Journal of Chemical Education*, XXIX (December 1952), 629–31.

[8] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks for High-School Physics." *Science Education*, XXXVI (February 1957), 19–23.

[9] Mallinson, George Greisen, Sturm, Harold E., and Patton, Robert E., "The Reading Difficulty of Textbooks for Elementary Science." *The Elementary School Journal*, L (April 1950), 460–3.

[10] Mallinson, George Greisen, Sturm, Harold E., and Mallinson, Lois Marion, "The Reading Difficulty of Textbooks in Junior-High-School Science." *The School Review*, L (December 1950), 536–40.

7. Recent textbooks in science are as variable and are likely to cause as much difficulty as earlier books analyzed.
8. The level of reading difficulty of textbooks of science appears to be a valid criterion for the selection of textbooks of science.

Although the studies carried out by Mallinson were completed many years later than those of Curtis, the results from them are similar. This would seem to indicate that little use was made of the earlier studies in improving the readability of textbooks in science.

In a study conducted by Crooks[11] the level of reading difficulty of textbooks in college science was investigated. The techniques used in this study were similar to those used by Mallinson in that use was made of the Flesch formula. However, the method of selection of samples was not specified.

Seventeen of the books selected for use in the study were in the areas of general biology (eight books), zoology (four books), botany (two books), anatomy and physiology (two books), and bacteriology (one book). The other books examined were one each in the areas of physical science, chemistry and physics.

The results of this study seem to indicate that all the books, as judged by the Flesch Human Interest Scale, are "dull." Eighteen of the books analyzed were found to be difficult according to the Flesch Scale, while two were found to be fairly difficult. Later editions of these books judged to be fairly difficult were found to rate as difficult.

While the results of this study seem to indicate that the results found by Mallinson at the elementary and secondary levels are also true for the college level, it should be pointed out that one textbook from a particular area is hardly representative of all textbooks written for use in that area.

Studies Dealing With the Ability of Teachers to Estimate the Reading Difficulty of Science Textbooks

Two studies were found in this area, one by Herrington[12] and a follow-up study by Mallinson and Holmes[13] in which similar techniques were used.

Herrington conducted a study to determine whether the measurements made with readability formulae of the reading difficulty of certain passages from textbooks for elementary sdience are more con-

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[11] Crooks, Kenneth B. M. and Smith, Charles H., "The Reading Problems in College Science Instruction." *Science Education*, XLI (February 1957), 54–7.

[12] Herrington, Roma Lenore, "An Investigation of the Consistencies With Which Readability Formulas Measure and Reading Experts Estimate the Reading Difficulty of Materials for Elementary Science." Unpublished master's thesis, Western Michigan College, Kalamazoo, Michigan, May 1956. Pp. iii+41.

[13] Mallinson, George Greisen and Holmes, Roma Herrington, "A Study of the Ability of Teachers to Estimate the Reading Difficulty of Materials for Elementary Science." A mimeographed report presented to the Convention of the National Council on Measurements Used in Education, St. Louis, Missouri, February 25, 1958.

sistent than estimates made by reading experts of the reading difficulty of these same passages.

In the study, samples were taken from Mallinson's studies of textbooks designed for grades four through eight. One hundred and ninety-nine samples from thirty-nine books were used in all.

Twenty-one of the one hundred and ninety-nine samples were selected at random and sent to twenty-six teachers classified as "reading experts" or "specialists in reading" in certain of the larger midwestern cities. These samples were accompanied by instructions for making estimates of the level of reading difficulty of the passages. The same passages were then evaluated, with respect to level of reading difficulty by the Flesch, Lorge, and Dale-Chall formulae of readability.

The results obtained by the readability formulae and the teachers' estimates were then compared. In general, the results indicate the following:

1. There is a great difference between the consistency with which the reading formulae evaluate the grade level of difficulty of the samples, and the consistency with which the reading experts evaluate the grade level of reading difficulty of the samples.
2. Readability formulae measure grade levels of reading difficulty of science materials with much more consistency than reading experts estimate grade levels of reading difficulty.
3. The evaluations made for higher level materials by both formulae and experts tend to be somewhat less consistent than those for lower level materials.
4. Teachers should have some method for evaluating materials as to reading difficulty which is more objective than their estimates.

In the study by Mallinson and Holmes cited above, the procedure used in Herrington's study was repeated, except that two elementary teachers in each of the school systems in which the experts were employed were requested to undertake the task of evaluating the sample passages.

The results were tabulated according to grade level of difference between the highest and lowest measurements or estimates of the level of reading difficulty of a sample, together with the number of samples for which that difference was evident.

The results indicated that the median difference for measurements by reading formulae is 1.0 years; for reading experts' estimates, 3.0 years; and for elementary teachers' estimates, 4.0 years. It was concluded that the use of reading formulae is justified, at least in so far as textbooks for elementary science are concerned.

Studies Dealing with the Selection of Science Textbooks

It should be pointed out that the quality of a textbook is related to

a number of factors. The studies summarized earlier indicate that an important criterion in the selection of science textbooks is the level of reading difficulty. Among other criteria are style of writing, organization of material; clarity of presentation; quality of illustrations; value of supplementary activities; and provisions for individual differences. Hence, it would seem that research related to the selection of reading materials falls within the province of this report. In one of these research investigations an evaluation scale for the selection of high-school science textbooks is proposed by Vogel.[14]

The scale is organized around ten general headings: qualification of the author; organization; content; presentation; accuracy; readability; adaptability; teaching aids; illustrations; and appearance. The scale is interpreted in numerical terms for convenience.

A similar scale has been proposed by Burr[15] that is organized around eight general headings.

In an article, Mallinson[16] suggests several points that should be considered in the selection of textbooks for science. These points are as follows:

1. The number of technical terms used in a textbook should be considered with regard for the "normal" increase in all vocabulary for a given grade level.
2. The technical terms should explain adequately the scientific meanings that are to be developed.
3. The technical words selected may include many that are nonessential to an adequate understanding of science at a given level. Further, many essential terms may have been omitted.
4. A careful analysis should include the use of a word-count system such as that of Buckingham and Dolch or a formula such as that of Flesch.

Summary

In summary, it could be stated that authors and publishers of textbooks for science might well take cognizance of the research that has been done on problems in reading science.

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[14] Vogel, Louis F., "A Spot-Check Evaluation Scale for High-School Science Textbooks." *The Science Teacher*, XVIII (March 1951), 70–2.

[15] Burr, Samuel Engle, "A Rating Scale for Textbooks." *The Journal of Education*, CXXXII (May 1949), 138–9.

[16] Mallinson, George Greisen, "Some Problems of Vocabulary and Reading Difficulty in Teaching Junior-High-School Science." School Science and Mathematics, LII (April 1952), 269–74.

SILENT SOUND AND STOMACHS

A Russian physiologist reports that secretion of gastric juice in the stomach is stimulated by sound waves too high to be heard by the human ear. Ultrasound of any intensity causes an increase in the amount and acidity of gastric juice in the stomach, M. K. Smirnov of Minsk has found. The stimulation lasts three days, he discovered in 94 tests on three dogs. Even low ultrasound intensities stimulate secretion if the stomach is empty. His study was reported by Central Intelligence Agency in a review of scientific work done behind the Iron Curtain.

Number Systems

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People in today's world are so accustomed to the use of the decimal or 10-digit number system that it requires a definite mental effort to either analyze the composition of our ordinary numbers or to visualize combinations in other number systems. Educators are beginning to realize that this mechanical use of the decimal number system has resulted in a generation of teachers and pupils who are hampered in scientific work and in the study of higher mathematics by their lack of basic understanding of the decimal system. Some work in the use of other number systems has been found to be helpful in bringing about a better understanding of the decimal system. Especially is this a profitable activity among rapid-learning pupils.

The steps called for in building number systems are as follows:

1. Determine how consecutive numbers are built in our 10-digit system.
2. Build numbers in a new digit system, and also build addition tables in this system
3. Arrive at a formula for writing a numeral of any value in the new system

Suppose that one wished to develop a five-digit number system. These five digits might be represented by:

0, 1, 2, 3, 4

The first digit, 0, would be a place-holder, just as it is in our 10-digit system, and the count would then be written:

1, 2, 3, 4, 10, 11, 12, 13, 14, 20, 21, 22, 23, etc.

A clearer understanding may be gained by examining the counting process in our 10-digit system. One writes, 8, 9, and then forms the next number by taking the first digit, 1, and places by it the 0, or the place-holder; then 11, 12, 13, etc., are formed by replacing the 0 with the consecutive digits until all nine have been used; the second digit, 2, is then used with all the other, and so on until 99 has been reached. The first digit is then used with two 0's to build a three-place numeral, 100. Primitive man, in building the 10-digit system, had an excellent built-in set of concrete objects to check by, his ten fingers and ten toes!

A new system of notation seems strange because, in western civilization, we have been trained from childhood to interpret the 10-digit scale automatically. The processes of adding and multiplying would be quite as easy in other systems if we worked out and memorized the combinations as we have done with the combinations of the 10-digit scale.

In the 5-digit system, addition tables would be like these:

1+1=2	2+1=3	3+1=4	4+1=10
1+2=3	2+2=4	3+2=10	4+2=11
1+3=4	2+3=10	3+3=11	4+3=12
1+4=10	2+4=11	3+4=12	4+4=13

to add numbers like 34 and 42 (from the 5-digit system) one proceeds as follows: from the table above we see that 2+4=11;

(1) write the right hand 1 and "carry" the other 1; then

$$\begin{array}{r} 34 \\ +42 \\ \hline 131 \end{array}$$

4+3+1 (carried)=13; this gives the answer 131.

The proof of this may be found by comparing the relative numbers in both the 5-digit and the 10-digit systems:

5-digit		10-digit
34	same as	19
+42	same as	+22
131		41

In the next step, the method of proving that the 131 is the same as the 41 will be explained.

How may one find equivalent numbers in the 5-digit or in any other digit system and the 10-digit system? Let us examine the number 14 in the 5-digit system: this number is made by taking one 10 and adding four 1's,

$$(1\times10)+(4\times1).$$

But in the 10-digit system, the 10 is written with a 5; substituting, we have:

$$(1\times5)+(4\times1) \text{ or } 9.$$

In a similar way examine the number 23 in the 10-digit system:

$$23 \text{ is equal to } (2\times10)+(3\times1).$$

The number 123 is made of $(1\times10^2)+(2\times10)+(3\times1)$

Now let us apply this reasoning to a problem:

"How is the number 38 of the decimal system written in the 5-digit system?"

Solution:

The highest power of 5 which is contained in 38 is 5^2 or 25; then

there are two 5's or 10; and finally three 1's.

$$\begin{array}{ll} 1\times5^{2} & 25 \\ 2\times5^{1} & 10 \\ 3\times5^{0(1)} & 3 \\ & \overline{38} \end{array}$$

But, in the 5-digit system, 5 is written as 10, therefore substitute 10 for the 5 and we have

$$\begin{array}{ll} 1\times10^{2} & 100 \\ 2\times10 & 20 \\ 3\times1 & 3 \\ & \overline{123} \end{array}$$

Therefore 38 is written 123 in the 5-digit scale.

Other systems can be used equally well in this manner. In writing a number in a 3-digit scale, the digits are 0, 1, 2. Hence 24 of the decimal scale is written 220 in the 3-digit scale.

Proof:

$24=(2\times3^{2})+(2\times3)+(0\times1)$ In the 3-scale, 3 is 10.

Sub. $(2\times10^{2})+(2\times10)$ Therefore, 24 is written 220 in the 3-digit scale.

SOME EQUIVALENTS IN OTHER SYSTEMS

Decimal	9-digit	7-digit	5-digit	3-digit	2-digit
24	26	33	44	220	11000
31	34	43	111	1011	11111
8	8	11	13	22	1000

Numbers written in the 10, 5, 3, or 2 scales are often said to be in the decimal, quinary, ternary, or binary scales. The binary scale has become of great importance to scientists especially electronic engineers. For example, in a simple circuit the current is either off or on; a *0* can represent the *off* and a *1* can represent the *on*. Calculations concerning whole banks of appliances are then made with the two digits. High and low voltage, gieger counters, half-life cycles for atomic reactors may also be computed by use of the binary system.

In the field of genetics where genes-count runs into astronomical figures, work is simplified by the use of a 12-digit or duodecimal system. It is interesting to note that in some ancient civilizations, notably the Babylonians, a 60-digit system was used. Since most of the records were made by cutting into stone tablets, the size of the numeral was an important factor to the writer.

PRACTICE PROBLEMS

1. Suppose a number system had the following 8 digits:

   □ ∧ Z Σ ⊦ S Б <
   0, 1, 2, 3, 4, 5, 6, 7

   a. Write the product of 8×8 of the decimal system

   b. What is the sum of ⊦ + Б + Σ

   c. What is the decimal equivalent of ∧ □ Σ Б

2. Write the decimal number 22 in the binary system
3. Add 34 and 43, which are both numbers of the 5-digit system. Prove your work by a complete check in the decimal system.
4. An electrician working on banks of lights decided to make his calculations using a binary system in which "off" was represented by X (place-holder) and "on" by I. His number count would run I, IX, II, IXX, III, etc.
   a. How would he write 13?
   b. What would be the decimal value of his IXXXXXX?
5. An ancient culture had a 12-digit system that was represented:
   0, 1, 2, 3, 4, 5, 6, 7, 8, 9, Y, X
   Rewrite these numbers in our decimal system:
   a. 23
   b. Y1

ANSWERS

1. a. ∧□□ b. ∧Б c. 546
2. 10110
3. 132. In decimal system, 34, 19, $\overline{43}$ 23, Sum is 42. In 5-digit system, 42 $=(10^2)+3(10)+2$ 132.
4. a. IIXI b. 128
5. a. 27 b. 122

NEWBORNS SEE BETTER THAN FORMERLY THOUGHT

Newborn babies can detect motion more sharply than was formerly thought, three doctors have reported.

A test of the detection of motion, by 100 babies, some less than one day old, revealed that their eyesight was much better than doctors had previously thought.

Each baby's eyesight was tested by placing him or her under an arc of paper. A pattern of equally wide black and white stripes, printed upon the paper, was then rolled across the arc above the baby's head, simulating the effect of a rotary cylinder.

The effect created by the motion of these stripes resembles what doctors call optico-kinetic nystagmus. This is simply the same as the effect of looking through a window in a moving train. The eyes of the passenger follow the passing telegraph poles in a rhythmic pattern.

Previous rough estimates on the acuity of infants placed it at 20/2500 at four months and 20/400 at six months. (As the child grows older, his acuity improves and eyesight approaches perfection, 20/20 vision.) The results of these tests indicate that newborn infants have 20/450 acuity, or roughly, vision that was believed to take six months to acquire. A large portion of the newborn did even better by registering acuity at 20/350.

The major value of the apparatus, will be to provide the physician with a definite clue to an infant's need for more examinations and treatment.

Magnetism and Some Interesting Magnets*

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Whether magnetism takes its name from a region in Asia Minor (Magnesia), as claimed by Lucretius, or from the shepherd Magnes, who was amazed to find the iron crook of his staff clinging to an overhanging rock, as related by Nisander and repeated by Pliny, we shall probably never know. That it always had, and still has, great fascination for anyone who sees it for the first or thousandth time is sure.

The first magnets were natural magnets, or lodestones. As might be expected of something so marvelous and apparently contrary to "common sense," these lodestones were objects of awe and superstition. What the people of the Dark Ages lacked in experimental knowledge they supplied by an abundance of imagination. We are told that, among other things, magnetism could cure disease; affect the brain, causing melancholia; and act as a love philtre. A magnet would lose its power when rubbed with garlic or in the presence of diamonds.

As science began to emerge from magic, it was discovered that a magnet could be made by holding an iron bar near a lodestone. It was noted that the attractive power was concentrated in places which we now call poles. Some time around the eleventh century it was discovered that when a magnet is freely suspended about a vertical axis one of the poles will set itself in a northerly direction. This knowledge enabled seamen to navigate their ships when out of sight of shore and gave them confidence to venture to unknown lands.

It is interesting to note that the Chinese knew of these phenomena as early as A.D. 121, but because of the total absence of communication, Europeans had to discover them independently.

The first person that we know of who gave magnetism serious experimental study was Peter Peregrinus, who published his "De Magnete" in 1269. Peregrinus made a large lodestone in the shape of a sphere, and by means of small magnets showed that this sphere had two poles somewhat similar to the earth. He also showed that "like" poles of a magnet repel each other, whereas "unlike" poles attract. He further demonstrated that when a magnet is broken in two, the parts are still magnets.

These achievements of Peregrinus seem all the more remarkable when we reflect that he was nearly alone in his age as being a scientist. The vast majority of so-called "scholars" of his day (and even as late as the seventeenth century) were content to quote Aristotle rather than investigate for themselves. A story goes that two learned

* Work done under the auspices of the U. S. Atomic Energy Commission.

men were involved in a rather heated argument about the number of teeth that a horse has. Each cited Aristotle at length, yet they were unable to settle the debate. All the time a horse was tied near by but neither disputant bothered to get his information "straight from the horse's mouth."

Later, William Gilbert, physician to Queen Elizabeth, extended Peregrinus's studies in a book which also bore the title "De Magnete." He showed that when a compass is held vertically the needle dips toward the earth. (This dip becomes greater at higher latitudes, and at the pole the needle will point directly into the earth.) Gilbert also found that a magnet loses its strength upon being heated, and that a steel bar becomes magnetized if it is jarred while in the field of another magnet. He attributed the earth's magnetism to deposits of iron ore. (Although the phenomenon of the earth's magnetism is not clearly understood to this day, it appears that this explanation probably is incorrect.[1]) And finally, Gilbert demonstrated that magnetization does not increase the weight of a magnet.

By the early nineteenth century science was progressing as never before. In 1819 Hans Christian Oersted, a Danish physicist, at the end of a lecture, accidentally placed a current-bearing wire over a compass needle and parallel to it. He was astonished to see the needle swing until nearly perpendicular to the wire. When he reversed the current in the wire, the needle swung in the other direction. Thus it was that electromagnetism was first observed.

Later experimenters found that an electromagnetic field can be greatly strengthened by winding the conductor to form a coil. Further strengthening can be obtained by putting an iron core in the coil. If this core is made of soft iron it loses most of its magnetism when the current in the coil is turned off. A steel core, on the other hand, will retain much of its field and become a "permanent" magnet. This ability to hold its field can be improved still further by various heat and pounding treatments. Small amounts of impurities also change the magnetic properties significantly. For instance, the permeability (magnetic quality) of pure iron is about 200; for supermalloy, an alloy of nickel and iron, it is more than 100,000. An alloy containing about 8% aluminum, 14% nickel, 24% cobalt, 3% copper, and the rest iron, will give permanent magnets retaining a field of more than 12,500 gauss. The "gauss" is a unit indicating the intensity of a magnetic field, and is equal to one line of magnetic force per square centimeter. We will be making reference to this term later to show the strengths of some of the world's largest magnets, but first we will consider different methods for measuring field strengths.

[1] For an interesting new theory of the earth's magnetism, see Walter M. Elsasser's, "The Earth as a Dynamo," *Scientific American*, May 1958, p. 44.

A very rough determination of a magnet's strength can be made by the weight of iron filings it will pick up. This method, however, is cumbersome, especially when dealing with very strong magnets. Furthermore, in many modern applications much more sensitive measurements are needed.

The earliest device for making reasonably accurate measurements of magnetic field strength was a torsion balance called a magnetometer. This was built by Charles A. Coulomb, a French physicist, and was used by him in 1785 to measure electrical as well as magnetic forces. His magnetometer consisted of a bar magnet suspended by a fine fiber so that it could rotate about a vertical axis through its center. The rest position of the magnet is aligned with the earth's field. If the magnet is twisted from this position a torque (force which produces a twisting motion) is set up, tending to urge the magnet's return to its rest position. By measuring this twist and by having previously derived the mechanical laws of his magnetometer, Coulomb was able to calculate the magnetic field strength. This early measurement provided the basis for all our quantitative knowledge of magnetic phenomena, and consequently may be considered a milestone in the experimental study of magnetism.

Other methods for measuring field strengths have been developed since the time of Coulomb, and some are more accurate. Most of these devices make use of the fact that magnetism can produce electricity. Before describing these devices, we must first consider the principle upon which they operate.

In 1830 Joseph Henry, an American, found that a current is produced in a conductor when it is moved in such a way that it "cuts" magnetic lines of force. Michael Faraday in England independently discovered the same thing soon after. Because Faraday published his

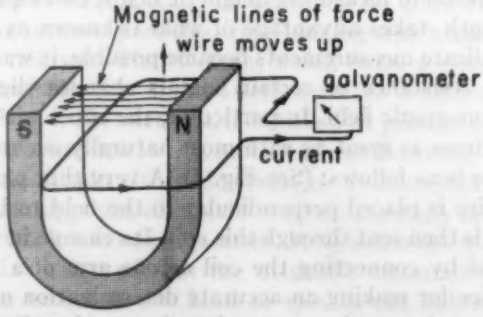


FIG. 1. A simple device for generating electric current. The wire is moved upward so that it cuts lines of magnetic force. A current flows through the wire and is registered by the galvanometer.

work first, he is usually given credit for the discovery. What they learned can be better understood by reference to Fig. 1. It is convenient to think of magnetic lines of force going from a north magnetic pole (N) to a south magnetic pole (S), as shown in the diagram. If the wire (W) is moved to the right or left no current will be produced. However, if it is quickly moved up, the galvanometer will record a sudden pulse of current. If the wire is moved down, the galvanometer will "kick" in the opposite direction. If the conductor is moved faster, or if the magnet is made stronger, the current will be greater.

Now we may examine several different methods for the more precise measurement of magnetic field strength. One system consists of a "flip coil" and a ballistic galvanometer, an apparatus for measuring the quantity of charge displaced by a current of short duration. The flip coil, which is mounted in the magnetic field to be measured, is mechanically flipped one-half turn. It cuts the lines of force and in so doing generates a current, which is in turn detected by the ballistic galvanometer. This process might be likened to opening a screen door against a spring—the harder the push, the wider the door opens. The current generated is compared to that produced with a magnet of known strength, and in this way the relative strengths are determined.

A ballistic galvanometer is not readily portable and requires a long time to get ready for the next "shot," so it is usually replaced by a cathode-ray oscilloscope (the granddaddy of the TV picture tube). This development of course did not occur until the twentieth century, after the invention of the electronic vacuum tube. Another improvement was to use a synchronous motor (like that in an electric clock) to keep the coil rotating at a constant rate, thus enormously increasing the output over a single flip of the coil, and vastly improving the sensitivity.

Another method of measuring magnetic fields, and especially those of great strength, takes advantage of what is known as the Hall effect. When delicate measurements became possible, it was found that the electrical resistance of certain metals changes slightly in the presence of a magnetic field. In particular, the effect with bismuth is hundreds of times as great as with most naturally occurring metals. The procedure is as follows: (See Fig. 2). A very thin pancake spiral of bismuth wire is placed perpendicular to the field to be measured and a current is then sent through this coil. Its change in resistance is then measured by connecting the coil as one arm of a Wheatstone bridge, a device for making an accurate determination of resistance. This change in resistance is compared to that produced when the bismuth coil is placed in a field of known strength. This method is par-

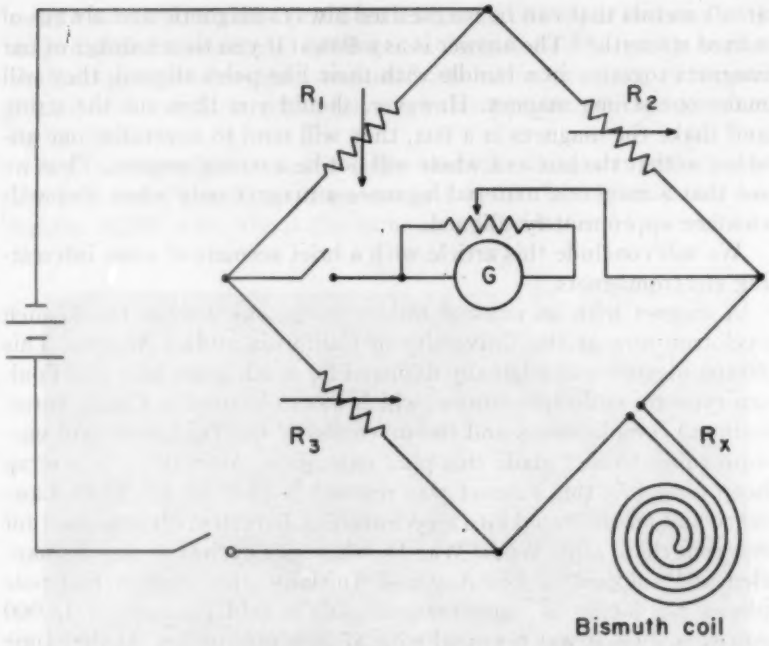


FIG. 2. Circuit for measuring magnetic field strength by the Hall effect. The bismuth coil R_x is connected as one arm of a Wheatstone bridge. R_1, R_2, and R_3 are variable resistors which have been previously calibrated. The operation of a Wheatstone bridge is described in any standard college physics text.

ticularly useful in measuring nonuniform fields and is quite accurate. A field of 16,000 gauss, for instance, can be measured with an accuracy of a few gauss.

We have told about magnetism and its measurement, but still haven't spoken of what it really is. To begin, we know that matter is made up of subatomic particles, chief among which are the proton, electron, and neutron. The electron, which bears a charge, spins on its own axis and revolves about another axis in a manner similar to the two motions of the earth. It is believed at present that all magnetic phenomena are due to this motion of the electron.

An electron can spin either clockwise or counterclockwise. If two electrons spin in opposite directions they nullify each other, and the molecule as a whole has no magnetism. Most nonmagnetic substances have their spins balanced, but the magnetic materials do not. The latter have an excess of one kind of spin in the following relative amounts: iron 2.2, cobalt 1.7, and nickel 0.61.

A thoughtful reader may ask, "If this explanation is correct, why

aren't metals that can be magnetized always magnetic and always of a fixed strength?" The answer is as follows: If you tie a number of bar magnets together in a bundle with their like poles aligned, they will make one strong magnet. However, should you then cut the string and shake the magnets in a box, they will tend to neutralize one another so that the box as a whole will not be a strong magnet. Thus we see that a magnetic material becomes a magnet only when its particles are appropriately aligned.

We will conclude this article with a brief account of some interesting electromagnets.

A magnet with an unusual history is the one used in the 37-inch cyclotron now at the University of California at Los Angeles. This 80-ton magnet was originally designed for spark quenching in a Poulsen-type arc radio transmitter, which was to be used in China. International complications and the invention of the De Forest grid vacuum tube (triode) made this plan unfeasible. After lying in a scrap heap for years, this magnet was rescued in 1931 by Dr. E. O. Lawrence and incorporated into a cyclotron at Berkeley. (It was used for research there after World War II, when this cyclotron was dismantled and shipped to Los Angeles). Initially, this magnet had pole pieces $27\frac{1}{2}$ inches in diameter and gave a field strength of 18,000 gauss. In 1936 it was rewound with 37-inch pole pieces. At that time it was referred to as the "giant magnet."

The construction of a much larger cyclotron, with a pole-piece diameter of 184 inches, was completed at the University of California Radiation Laboratory in Berkeley in 1946. When first built it had a magnet containing 3700 tons of steel, with 300 tons of copper in the coil windings. During the war this magnet was used to produce the first significant amounts of fairly pure uranium-235. In 1955 this cyclotron was rebuilt; 4000 tons of steel went into the yoke of the magnet, which has a field strength of 23,400 gauss.

The electromagnetic method used to separate the isotopes of uranium requires a uniform field. At Oak Ridge, Tennessee, 96 vacuum tanks and an equal number of magnets were grouped together in the shape of a race track. The dimensions of each tank were about $4 \times 8 \times 2$ feet. A uniform field of approximately 3000 gauss had to be maintained throughout the entire volume of 6400 cubic feet—a world's record at that time (1943). When this isotope separator was built there was a great shortage of copper, so the coils for several magnets were wound with silver from the U. S. Government supply at West Point. Nearly 20,000 tons of silver were used, having a value close to $400,000,000. The coils have since been rewound with copper.

The Bevatron magnet at Berkeley weighs 9,700 tons (about the

same as a medium cruiser) and uses 347 tons of copper in its coils. Its magnetic field measures 16,000 gauss. It may be interesting to note that a magnet of this size consumes 3,500 kilowatts of electricity each hour it is in operation, which is enough to supply an average community of 30,000.

A proton synchrotron even larger than the Bevatron is the Soviet Union's new Phasotron, whose magnet is 200 feet in diameter and weighs 36,000 tons, about the same as a World War II aircraft carrier.

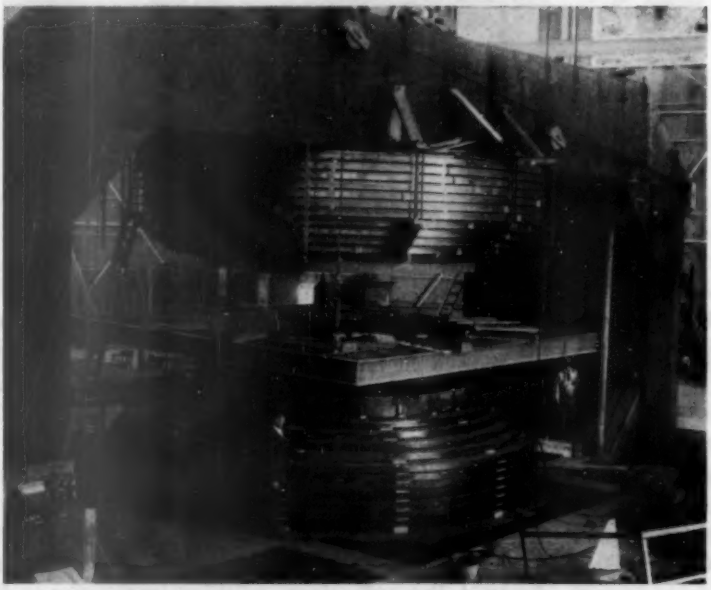


FIG. 3. Magnet yoke and main coils of the 184-inch synchrocyclotron at the Lawrence Radiation Laboratory, University of California, Berkeley. This photograph shows the magnet during construction; the coils are now enclosed in tanks and cooled by circulating oil.

At Brookhaven National Laboratory, Upton, Long Island, a new accelerator is being constructed which will have a ring-shaped magnet 840 feet in diameter. Not to be outdone, the Russians are reportedly working on an even larger version of the Brookhaven machine with a ring-shaped magnet 1,500 feet in diameter.

The world's most powerful continuously operating magnet is located in the low-temperature laboratory of Nobel prize winner W. R. Giauque on the campus of the University of California at Berkeley. This magnet has no iron core because its field is so great (97,500 gauss) that the iron would saturate and thus be of no value. The coil

FIG. 4. Aerial view of a giant proton synchrotron now under construction at Brookhaven National Laboratory, Upton, Long Island. The ring-shaped magnet is 840 feet in diameter. Astride the tunnel, on the right, is the target building which will house the indoor laboratory area. This machine will accelerate protons to 25 billion electron volts (Bev).

that produces this enormous field uses 9,500 amperes of current and must be cooled with kerosene, which is in turn cooled by water. At present this magnet is being rebuilt to give an even larger field.

Other magnets have been built to give pulsed fields of a much higher strength. In 1924 Peter Kapitza, working in the Cavendish Laboratory at Cambridge, England, produced a transient field of 100,000 gauss by discharging the current from a large number of storage batteries through a coil. In 1927 this was increased to 320,000 gauss by using the energy stored in the flywheel of a moving generator. This system made switching easier, since in an alternating current there is periodically no current, and the circuit can then be opened without serious arcing.

This limit was pushed to 450,000 gauss by T. F. Wohl, using a capacitor bank as his source of power. His magnets, like flashbulbs, could be used only once because the terrific fields generated blew the coils apart. By November, 1957, Furth, Levine, and Waniek obtained a transient field up to 1.6 million gauss before their beryllium-copper coil melted. This is the record to date, but new magnets of ever increasing magnitude are being designed.

Lucretius believed in "atoms and the void" at a time in antiquity when these concepts were merely speculations of the mind and unconfirmed by experiment. He gave advice on how to live and how to die which many people today regard as unsurpassed in wisdom and foresight. But surely Lucretius never dreamed of the offspring of his "Samothracian rings which leaped up, and the iron filings which seethed so furiously in the brazen bowl when underneath was the magnet stone."

Mathematics in the Dark

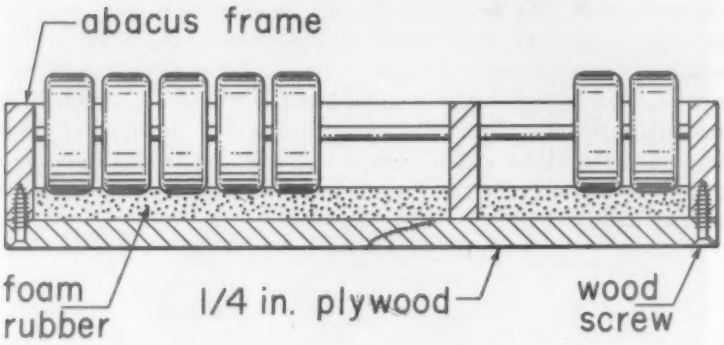
Edward Calhoon
112 Price Lane, Pleasant Hill, California

A young friend of mine who has been blind since birth is now a senior in a public high school, where he has been an "A" student in all courses except those requiring mathematical ability. At the school for the blind which he attended earlier he was taught to perform problems in this head, without the help of any mechanical aid. As you know, this is fine for short problems, but is very difficult and uncertain when large numbers are involved.

Last fall he enrolled in physics, although he had been advised that his preparation in mathematics was inadequate. He soon found that this was true. He had little difficulty understanding the physical concepts, and he was able to perform most of the experiments, or at least grasp their significance. But unless he could improve his mathematical ability quite soon, he would have to discontinue, owing to his lack of facility in handling the calculations. In short, it was not the physics, but the mathematics that promised to defeat him.

One evening he was discussing his problem with me and I asked him if he had ever tried using a Chinese abacus. "What's that?" he replied. I described one to him, telling him how it can be used to add, subtract, multiply, divide, or extract square and cube roots. He thought he might be able to use one, providing some way could be found to keep the beads from slipping accidentally.

I cut a piece of $\frac{1}{2}$-in.-thick foam rubber to fit up under the beads of an abacus my friend purchased in San Francisco's China Town, where this ancient calculator is still commonly used by merchants. The foam rubber is held in place by means of a piece of $\frac{1}{4}$-in.-thick plywood screwed to the frame of the abacus. The foam rubber then compresses against the underside of the beads so that they can slide only if pushed.



We next proceeded to learn how to use the abacus, and in just a few sessions became fairly accomplished in addition and subtraction, which can be done to twelve significant figures. At this point, Mr. Gus Edwards, a mathematics instructor at Pleasant Hill High School[1] where the boy attends, showed him how to use logarithms. The boy was able to get a copy of log tables in Braille and soon became proficient in using them in connection with the abacus.

He found this very convenient, since it is not necessary to write down any numbers. He merely looks up the first value and places it on the abacus; the second value is then added or subtracted from the first value directly, depending on whether he is multiplying or dividing. The answer is presented at the same time the calculation is performed. This method is as swift as it is accurate.

As a result of his new ability, my friend is no longer troubled by the mathematics and can now concentrate on the physics. By the end of the first semester he had brought his grade up to a "B" and his instructor is optimistic that he can get an "A" the second semester.

I see no reason why a blind child could not be taught the abacus in the elementary grades, so that by the time he reached high school he would have thoroughly mastered it and be able to enter courses in science and mathematics with confidence.

ACKNOWLEDGMENT

I am grateful to Mr. Henry Chang of San Francisco for preparing the drawing.

[1] Pleasant Hill, California.

Polar Roses

William R. Ransom

Tufts University, Medford, Mass.

Plotting in polar coordinates is often done by merely locating points and connecting them. This leads to putting cusps where they do not belong, especially at the ends of leaf- or rose-curves. To draw a beautifully accurate graph of $r = a \sin n\theta$, three sorts of guides are valuable: tangents at the pole, mid-quadrant points, and vertex circles.

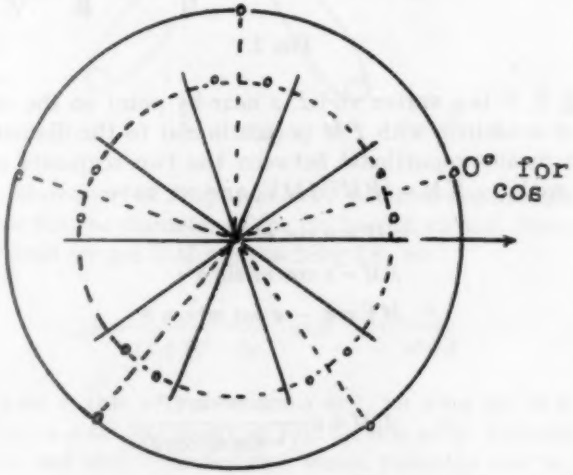


FIG. 1.

I. Draw a circle about the pole of radius a (full line in Fig. 1), and a concentric circle (dotted in Fig. 1) of radius $a/\sqrt{2}$; seven-tenths of a is good enough for plotting. These circles contain the vertices and the mid-quadrant points.

II. Draw radii at $180°/n$ intervals, the first being at 0° for $r = \sin \theta$, but at $\theta = 90°/n$ for $r = a \cos n\theta$. These are the full lines in Fig. 1, and are the tangents along which the curve enters the pole.

III. Draw radii (dotted in Fig. 1) at $360°/n$ intervals, bisecting alternate angles formed by tangents, and cutting the outer circle at the vertices.

IV. On the dotted circle, locate points bisecting the arcs between the vertex radii and the tangents. These points are half-way between the beginning and end of $n\theta$'s quadrants; the curve must pass through them because they have $r = 1/\sqrt{2}$, which is the value of sines and cosines of mid-quadrant angles.

V. At each vertex, draw a circle of radius $a/(n^2+1)$, internally tangent to the outer circle. The petals of the rose must fit these circles very closely, as shown in Fig. 3. To explain this it is best to consider $r = a \cos n\theta$, which differs from $r = a \sin n\theta$ only by a rotation through $90/n$ degrees.

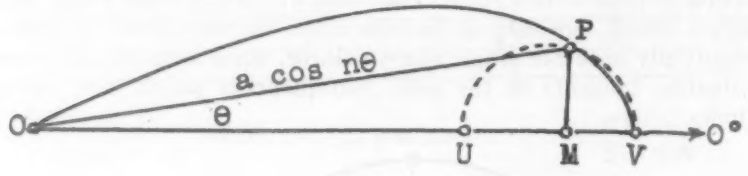


FIG. 2.

In Fig. 2, V is a vertex and P a near-by point on the curve, and VPU is a semicircle with PM perpendicular to the diameter. Since PM is a mean proportional between the two segments of the diameter* we have $UM = (PM^2)/MV$, and we have

$$OP = a \cos n\theta$$

$$PM = a \cos n\theta \sin \theta$$

$$MV = a - a \cos n\theta \cos \theta$$

whence

$$UM = a \cdot \frac{(\cos n\theta \sin \theta)^2}{1 - \cos n\theta \cos \theta}$$

When θ approaches zero, this approaches the same limit as

$$\frac{a \sin^2 \theta}{1 - \cos n\theta \cos \theta} = \frac{a \sin^2 \theta}{1 - \cos (n+1)\theta - \sin n\theta \sin \theta}$$

$$= \frac{a \sin^2 \theta}{2 \sin^2 \left(\frac{n+1}{2}\right)\theta - \sin n\theta \sin \theta}$$

$$= \frac{2a}{4\left\{\frac{\sin^2\left(\frac{n+1}{2}\right)\theta}{\sin \theta}\right\}^2 - 2\frac{\sin n\theta}{\sin \theta}}$$

For very small angles, the angles are very nearly proportional to their sines, and so as θ approaches zero, the limit of $(\sin k\theta/\sin \theta)$ is

* Compare a similar treatment of the vertex circle of a parabola on page 135 of SCHOOL SCIENCE AND MATHEMATICS for Feb. 1959.

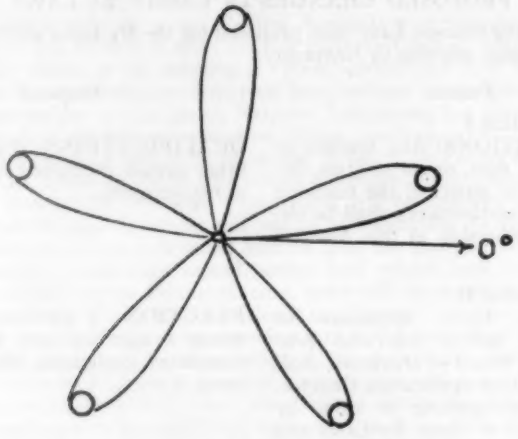


FIG. 3.

$k\theta/\theta$, or k. Moreover, as P approaches V, M also approaches V, and UM approaches the diameter of the circle wish to find. Hence, passing to the limit we get UM approaching $2R$, so

$$2R=\frac{2a}{(n+1)^2-2n} \quad \text{and} \quad R=\frac{a}{n^2+1}$$

For $r=a \sin \theta$, this vertex radius is $a/2$; for $r=a \sin 2\theta$ it is $a/5$, etc., and for $r=a \sin 5\theta$ (shown in Fig. 3), it is $a/26$. The slimness of these petals and their rounded tips would probably not be plotted correctly without the aid of the mid-quadrant points and the vertex circles.

ROAD-BUILDING MACHINE HAS 8 ELECTRIC WHEELS

A new road-building machine has eight electrically driven, six-foot wheels. It can self-load and haul 50 tons of dirt in one trip.

Built by R. G. LeTourneau, Inc., here, the machine has an electric motor geared into the hub of each wheel. These motors, as well as other motors spotted over the machine, are powered by a dynamo under the hood, which is driven by a 600-horsepower diesel engine.

The machine has two "buckets," not so much to haul the 50-ton capacity, but mainly to facilitate self loading. The rear bucket serves as a pusher to help load the front bucket. The weight of the loaded front bucket then increases tire traction to help pull-load the rear bucket.

During this operation, the bottom of each bucket becomes a huge electrically controlled spade, digging and scooping to load itself.

Simple electric controls govern all functions of the 74-foot-long machine. No clutches, transmission or other mechanical-drive components are used.

PROPOSED CHANGES IN CASMT BY-LAWS

The following changes have been proposed for the By-Laws and will be voted on at the annual meeting in November.

Present	*Proposed*
Article I, Section I QUALIFICATIONS: Any teacher or other person, firm, or corporation, interested in any aspect of the teaching of science or mathematics shall be eligible for membership in this Association.	QUALIFICATIONS: Any teacher or other person interested in any aspect of teaching, etc.
Article I, Section II ELECTION: Every applicant for membership, unless otherwise provided by the Board of Directors, shall present a written application therefor, accepting and agreeing to abide by the provisions of these By-Laws and amendments thereto, which application shall be submitted to the Secretary, or any officer of this Association, and referred by him to the Committee on Membership for its approval or disapproval. The application, together with recommendations of the Committee on Membership, shall be submitted to and acted upon by the members of the Board of Directors. A two-thirds vote of the members present at any regular meeting of the Board of Directors shall be sufficient to elect to membership.	ELECTION: A qualified person becomes a member upon submitting a completed application blank and payment of dues.
Article I, Section III TERMINATION OF MEMBERSHIP: The membership of any nember of the Association shall be automatically terminated for any delinquency of dues, or other charges owing to the Association, continued for a period of six months. Any member of the Association, etc.	TERMINATION OF MEMBERSHIP: membership of any member of the Association shall be automatically terminated for any delinquency of dues, or other charges owing to the Association. During the first six months of such delinquency the person may upon request and payment of back dues be restored to membership without losing continuity of membership. Any member of the, etc.
Article V, Section V: PROGRAM COMMITTEE: The Chairman, Vice-Chairman, and Secretary of each of the sections provided for in the next preceding paragraph, together with the Officers of the Association, shall constitute a Program Committee. The Program Committee shall prepare and have charge of the program of the annual meeting of the Association.	PROGRAM COMMITTEE: The program committee shall consist of the chairmen of all sections, the Vice-President, and other such members as the President may appoint. The Vice-President shall act as chairman of this committee. The program committee shall prepare and have charge, etc.

1959 CASMT CONVENTION

The 1959 annual meeting of the Central Association of Science and Mathematics Teachers will be held at the Congress Hotel in Chicago, Illinois, November 26–28. The theme of the meeting is "New Science and New Mathematics for a New Era." Outstanding speakers have been invited for the general sessions. Dr. A. S. Householder of Oak Ridge National Laboratory has accepted the invitation to speak at the general session on Friday morning.

As at the two previous meetings, there will be tours, on Friday afternoon, to places of interest. There will be also on Friday afternoon, three interesting panels on "Modern Curriculum Problems." One panel will be devoted to Biological Sciences, one to Physical Sciences, and one to Mathematics. As panelists there will be a representative on each panel from each of the four instructional areas: elementary school, junior high school, senior high school, and junior college. After the general session on Friday evening, there will be an informal reception where old friends can be seen and new friends can be met.

The general session on Saturday morning introduces something entirely new to the CASMT program. The membership of the Association is being invited (consider this statement as your personal invitation) to submit titles for short papers to be presented. A strict time allotment of five to ten minutes will be given to those selected for presentation. Secretary Joe Kennedy will act as chairman of this general session. If you have an idea for the improvement of the teaching of science or mathematics which you would like to present on such a program write to Joe Kennedy, 1612 Matlock Road, Bloomington, Indiana. Tell him what your idea is and give him an outline of the suggested pattern of presentation.

The section meetings will follow immediately after this general session. The sectional chairmen are at work preparing interesting and challenging programs for you.

The following individuals will serve as guest speakers for the various meetings.

Dr. Hubert N. Alyea, Princeton University
Dr. Lawrence Hubbell, Science Consultant Oak Park Schools
Dr. Carl Mapes, Chief Map Editor, Rand McNally and Company
Leonard E. A. Batz, Scientific Gyro Advisor, General Motors Corporation
William Golomski, Manager Operations Research, Oscar Mayer and Company
Bruce R. Vogeli, Bowling Green State University
Dr. Francis E. Throw, Argonne National Laboratory
Dr. Elbert P. Little, Educational Services, Inc.
Dr. Gilbert Finlay, University of Illinois
Dr. Guenter Swartz, University of Florida

Let us all combine our efforts to make this annual meeting one of the best sessions of CASMT on record!

F. LYNWOOD WREN, *Chairman*

PHYSICS EQUIPMENT

It has been announced that effective September 30, 1959, J. Klinger Scientific Apparatus Co., 82–87, 160th St., Jamaica 32, N. Y., will be the sole distributor in the United States for E. Leybold, Cologne, West Germany, manufacturers of equipment for teaching physics.

PROBLEM DEPARTMENT

Conducted by **Margaret F. Willerding**

San Diego State College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the Department desires to serve her readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

LATE SOLUTIONS

2614, 2656. *Calvin A. Moe, Ames, Iowa.*

2654, 2658. *J. Byers King, Denton, Md.*

2663. *Sister Miriam Jean, Milwaukee, Wis.*

2648, 2651, 2652, 2657. *C. W. Trigg, Los Angeles, Calif.*

2664. *Proposed by John Barry Love, St. Davids, Pa.*

Show that two colors suffice to color any map with corners of even order if the surface is a plane.

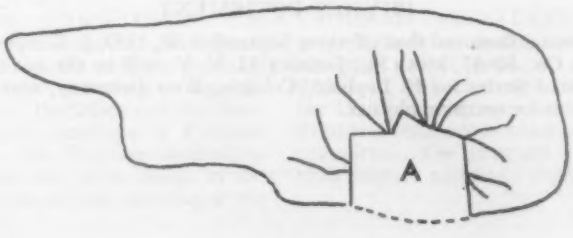
Method 1

Solution by the proposer

The proposition is easily proved by an induction on the number of countries.

Certainly we can color any map of one country. We see that it is also possible to color in the required manner any map consisting of a single star of even order.

To complete the induction, take any map consisting of even ordered vertices and look at all but one country $(n-1)$ colored correctly.



If we traverse the boundary of country A, we observe that every country that touches A is necessarily of the same color. It is also seen that every vertex is of even order. To complete the coloring of the entire map, we color country A with the other color and place it on the map. The induction is complete.

Method 2

Solution by C. W. Trigg, Los Angeles City College

Since the intersections of the boundaries of all countries are of even order, two colors may be alternated around any node, and the process may be repeated about all other nodes on the boundary of a colored country until the map is completely colored.

2665, *Proposed by Alan Wayne, Baldwin, N. Y.*

Determine the triangle whose sides are integers and whose perimeter is $2\sqrt{3}$ times the area of the triangle.

Solution by C. W. Trigg, Los Angeles City College

Considering the problem non-dimensionally,

$$a+b+c=2\sqrt{3}[\tfrac{1}{2}r(a+b+c)].$$

Hence $r=\frac{1}{2}\sqrt{3}$, and one such triangle is the equilateral triangle with sides equa to 2.

Solutions were also offered by Merrill Barnebey, Tougaloo, Miss; Donald Byrkit, West Chicago, Ill.; W. R. Talbot, Jefferson City, Mo.; and Dale Woods, Pocatello, Idaho.

2666. *Proposed by Brother Felix John, Philadelphia, Pa.*

A general wishing to draw up his regiment into a square found by trial that he had 92 men over; he then increased each side by two men, and wanted 100 men to complete the square. How many soldiers did he have?

Solution by H. R. Leifer, Pittsburgh, Pa.

Let x be the number of men on a side of the original square, then

$$x^2+92=(x+2)^2-100,$$

from which it is easily found that $x=47$, and that the number of soldiers, x^2+92, is 2301.

Solutions were also offered by Robert Atkins, Brooklyn, N. Y.; Merrill Barnebey, Tougaloo, Miss.; Donald Byrkit, West Chicago, Ill.; Louis S. Cohen, Los Angeles, Calif.; Benjamin Greenberg, Fort Hamilton High School, Brooklyn, N. Y.; J. Byers King, Denton, Md.; Bruce Lawhun, Springfield, Ohio; J. H. Means, Austin, Texas; Carl H. Spray, Brookfield, Ind.; Walter R. Talbot, Jefferson City, Mo.; C. W. Trigg, Los Angeles, Calif.; Dale Woods, Pocatello, Idaho; and the proposer.

2667. *Proposed by L. Van Tassel, San Diego, Calif.*

Calculate

$$\sqrt[\pi]{i}=(i)^{1/\pi}=?.$$

Solution by W. R. Talbot, Jefferson City, Missouri

We may express i as a complex number in trigonometric form with amplitude

$$\frac{\pi}{2}+2\pi k$$

where $k=0, 1, 2, \cdots$. Then

$$i^{1/\pi}=\left[\cos\left(\frac{\pi}{2}+2\pi k\right)+i\sin\left(\frac{\pi}{2}+2\pi k\right)\right]^{1/\pi}.$$

Since DeMoivre's Theorem is valid for real exponents, we have

$$i^{1/\pi} = \cos(\tfrac{1}{2}+2k)+i\sin(\tfrac{1}{2}+2k) \text{ where } k=0, 1, \cdots.$$

If $k=0$, the root is

$$.87758+i.47943.$$

Solutions were also offered by Merrill Barnebey, Tougaloo, Miss.; Donald Byrkit, West Chicago, Ill.; Yen-Yeh Liu, New Orleans, La.; C. W. Trigg, Los Angeles, Calif.; Dale Woods, Pocatello, Idaho; and the proposer.

2668. *Proposed by J. Byers King, Denton, Md.*

The first eight terms of a series are

$$0, \quad -68, \quad -232, \quad -510, \quad -896, \quad -1360, \quad -1848, \quad -2282.$$

What is a formula for a_n and what is the first positive term of the series?

Solution by Donald Byrkit, West Chicago, Ill.

By calculation of the successive differences between the terms of the series we obtain

$$\begin{array}{cccccccc}
0, & -68, & -232, & -510, & -896, & -1360, & -1848, & -2282 \\
 & -68, & -164, & -278, & -386, & -464, & -488, & -434 \\
 & & -96, & -114, & -108, & -78, & -24, & 54 \\
 & & & -18, & 6, & 30, & 54, & 78 \\
 & & & & 24, & 24, & 24, & 24
\end{array}.$$

A formula for a_n, then, will be a fourth degree equation in n. By antidifferentiation we obtain

$$\begin{aligned}
a_n^{IV} &= 24 \\
a_n^{III} &= 24n+k_1 \\
a_n^{II} &= 12n^2+k_1n+k_2 \\
a_n^{I} &= 4n^3+\tfrac{1}{2}k_1n^2+k_2n+k_3 \\
a_n &= n^4+(1/6)k_1n^3+\tfrac{1}{2}k_2n^2+k_3n+k_4.
\end{aligned}$$

To obtain four equations for the four unknowns, let $n=1, 2, 3, 4$.

$$\begin{aligned}
a_1 &= 1+(1/6)k_1+\tfrac{1}{2}k_2+k_3+k_4=0 \\
a_2 &= 16+(1/6)(8)k_1+\tfrac{1}{2}(4)k_2+2k_3+k_4=-68 \\
a_3 &= 81+(1/6)(27)k_1+\tfrac{1}{2}(9)k_2+3k_3+k_4=-232 \\
a_4 &= 256+(1/6)(64)k_1+\tfrac{1}{2}(16)k_2+4k_3+k_4=-510.
\end{aligned}$$

These equations simplify to

$$\begin{aligned}
k_1+3k_2+6k_3+6k_4 &= -6 \\
4k_1+6k_2+6k_3+3k_4 &= -252 \\
9k_1+9k_2+6k_3+2k_4 &= -626 \\
32k_1+24k_2+12k_3+3k_4 &= -2298.
\end{aligned}$$

The above system of equations may be represented by the matrix

$$\begin{bmatrix}
1 & 3 & 6 & 6 & -6 \\
4 & 6 & 6 & 3 & -252 \\
9 & 9 & 6 & 2 & -626 \\
32 & 24 & 12 & 3 & -2298
\end{bmatrix}$$

This matrix may be written in reduced echelon form as follows:

$$\begin{pmatrix} 1 & 3 & 6 & 6 & -6 \\ 0 & 2 & 6 & 7 & 76 \\ 0 & 0 & 6 & 11 & 112 \\ 0 & 0 & 0 & 1 & 14 \end{pmatrix}$$

from which $k_4=14$, $k_3=-7$, $k_2=10$, $k_1=-78$. A general form for a_n, then, is

$$a_n=n^4-13n^3+5n^2-7n+14.$$

By inspection it is seen that a_{12} will be the first positive term of the series.

$$a_{12}=13^4-13^4+845-91+14=768.$$

Solutions were also offered by Robert A. Atkins, Brooklyn, N. Y.; Sr. Mary Constance, C.S.A., Fond du Lac, Wis.; Phillip H. C. Fung, Pocatello, Idaho; Jack Goldberg, West Englewood, N. J.; Felix John, Philadelphia, Pa.; H. R. Leifer, Pittsburgh, Pa.; J. H. Means, Austin, Texas; Cecil B. Read, Wichita, Kans.; W. R. Talbot, Jefferson City, Mo.; C. W. Trigg, Los Angeles; and the proposer.

2669. *Proposed by Lee H. Mitchell, Glencoe, Ill.*

When the reverse of one-third of my age is subtracted from the reverse of half my age, the result decreased by my age nine years ago reversed will be exactly equal to my age in eight years. How old am I?

Solution by C. W. Trigg, Los Angeles City College

The age, A, must be exactly divisible by Z and by 3. It also is greater than 9. Let $R(x)$ be the reverse of x. Then if $A\equiv 0 \pmod 9$, $R(\frac{1}{2}A)\equiv 0$, $R(\frac{1}{3}A)\equiv 0$, and $R(A-9)\equiv 0 \pmod 3$. But $(A+8)\not\equiv 0 \pmod 3$. So perhaps

$$A=12, *24, 30, *42, (48), (60), (66), (78), *84, \text{ or } 96.$$

For the asterisked values,

$$R(\tfrac{1}{2}A)<R(\tfrac{1}{3}A).$$

For the values in parentheses,

$$R(\tfrac{1}{2}A)<R(A-9).$$

For 12 and for 96,

$$R(\tfrac{1}{2}A)<R(\tfrac{1}{3}A)+R(A-9).$$

Thus the only possible value of A is 30, and indeed $51-01-12=38$.

Solutions were also offered by Merrill Barnebey, Tougaloo, Miss.; W. R. Talbot, Jefferson City, Mo.; and Dale Woods, Pocatello, Idaho.

2670. *Proposed by W. W. Johnson, Cleveland, Ohio.*

A stone is dropped from the top of a tower. When this stone has fallen H feet, another stone is dropped from a point h feet below the top of the tower. The two stones reach the ground at the same instant. Find the height of the tower.

Solution by proposer.

Let D be the height of the tower.

Assuming the law $s=gt^2/2$ then the time for the first stone to fall the distance H is $\sqrt{2H/g}$ and to fall the distance D is $\sqrt{2D/g}$. The time for the second stone to fall is $\sqrt{2(D-h)/g}$.

Therefore

$$\sqrt{2D/g}-\sqrt{2H/g}=\sqrt{2(D-h)/g}$$

$$\sqrt{D}-\sqrt{H}=\sqrt{D-h}$$

$$D-2\sqrt{DH}+H=D-h$$

$$2\sqrt{DH}=H+h$$

$$4DH=(H+h)^2$$

$$D=(H+h)^2/4H.$$

Solutions were also offered by Robert A. Atkins, Brooklyn, N. Y.; Merrill Barnebey, Tougaloo, Miss.; J. Byers King, Denton, Md.; W. R. Talbot, Jefferson City, Mo.; and C. W. Trigg, Los Angeles, Calif.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2665, 2666, 2667, 2668, 2669, 2670. *Lee H. Mitchell, Glencoe, Ill.*

2666. *Enid Oppenheimer and Barbara Kiken, Fort Hamilton High School, Brooklyn, N. Y.*

2666. *Tom Rochow, Jim Gunnels, John Mattingly, David Rutkowski, and Robert Peroutka, all of St. Mary's High School, St. Louis, Mo.*

2666. *Glen Carls, Beardstown, Ill.*

2666. *Lutz Dahlke, San Diego, Calif.*

2666. *Winefred Koebel, Chicago, Ill.*

2666. *Patricia Lemm, Chicago, Ill.*

2666. *Robert Lindsay, Chicago, Ill.*

2666. *Ann Maria Midrail, Chicago, Ill.*

PROBLEMS FOR SOLUTION

2689. *Proposed by Cecil B. Read, University of Wichita, Wichita, Kans.*

Prove that if the ratio $(z-i)/(z-1)$ is purely imaginary the point z lies on the circle whose center is at the point $\frac{1}{2}(1+i)$ and which has a radius $\frac{1}{2}\sqrt{2}$.

2690. *Proposed by Leo Moser, University of Alberta.*

In how many ways can a king go from the left lower corner of a chessboard to the right upper corner, if the permissible moves are single steps horizontally to the right, vertically up and diagonally up and to the right?

2691. *Proposed by C. W. Trigg, Los Angeles City College.*

There are two numbers each with three like middle digits, and such that each of their squares is a permutation of the digits from zero through eight. Find them and show that there are no others.

2692. *Proposed by J. B. Flansburg, Houston, Texas.*

The fifty-two cards of a "well-shuffled" deck are laid out in a row. Directly below these are placed the cards of another deck, similarly prepared. What is the probability that there will be at least one matching of two like cards?

2693. *Proposed by Lloyd A. Walker, San Mateo, Calif.*

Find the "volume" common to n mutually perpendicular intersecting cylinders in n-dimensions each of radius a and having their axes concurrent.

2694. *Proposed by Cecil B. Read, University of Wichita, Wichita, Kans.*

Determine the real values of x for which $1/x+1(x+1)$ exceeds $\frac{1}{4}$.

Books and Teaching Aids Received

WORKING WITH ANIMALS, by J. Myron Atkin and R. Will Burnett, *University of Illinois*. Paper. Pages viii+67. 15.5×23 cm. 1959. Rinehart & Company, Inc., New York, New York. Price $1.00.

WHAT IS SPACE, by Matthew F. Vessel and Herbert H. Wong. Paper. 14 pages. 14×22 cm. 1959. Fearon Publishers, 2263 Union Street, San Francisco, California. Price $.75.

BASIC PHYSICS FOR SECONDARY SCHOOLS, by Howard L. Eubank, *Vice-Principal, Etobicoke Collegiate Institute, Toronto, Ontario*, John M. Ramsay, *Inspector of Science for Secondary Schools, Ontario*, and Leslie A. Rickard, *Head of Science, Department, Forest Hill Collegiate Institute, Toronto, Ontario*. Cloth. Pages xiv+416. 15×23.5 cm. 1959. St. Martin's Press, Inc., 103 Park Avenue, New York 17, New York. Price $3.00.

WHITEFOOT MOUSE, by Barbara & Russell F. Peterson. Cloth. 53 pages. 15×20 cm. 1959. Holiday House, 8 West 13th Street, New York 11, New York. Price $2.50.

EXPLORING PHYSICS, by Richard F. Brinckerhoff, Judson B. Cross, and Arthur Lazarus. Cloth. Pages xi+723. 15.5×23.5 cm. 1959. Harcourt, Brace and Company, Inc., 750 Third Avenue, New York 17, New York. Price $5.20.

THE AUTOBIOGRAPHY OF CHARLES DARWIN AND SELECTED LETTERS, Edited by Francis Darwin. Paper. Pages vi+365. 13.5×20.5 cm. 1959. Dover Publications, Inc., 180 Varick Street, New York 14, New York. Price $1.65.

EXPERIMENTAL ELECTRICITY FOR BOYS, by Willard Doan. Cloth. Pages iv+124. 19×27.5 cm. 1959. John F. Rider, Inc., 116 West 14th Street, New York 11, New York. Price $3.45.

PLANE TRIGONOMETRY, by A. W. Goodman, *Professor of Mathematics and Astronomy, University of Kentucky*. Cloth. Pages xvii+267. 14.5×22.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $4.50.

PLANE TRIGONOMETRY, by Nathan O. Niles, *Associate Professor, Department of Mathematics, U. S. Naval Academy, Annapolis, Maryland, Lecturer in Mathematics, McCoy College, The John Hopkins University, Baltimore, Maryland*. Cloth. Pages xi+234. 14.5×22.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $3.95.

STATE SCHOOL LEGISLATION, 1957, by Arch K. Steiner, *Education Research and Program Specialist, Laws and Legislation Branch.* Paper. Pages iv+189. 14×22.5 cm. 1959. U. S. Department of Health, Education, and Welfare, Office of Education, Washington, D. C. Price $.70.

FREE AND INEXPENSIVE PICTURES, PAMPHLETS, AND PACKETS FOR AIR/SPACE AGE EDUCATION, Second Edition. Paper. 22 pages. 21×27.5 cm. National Aviation Education Council, 1025 Connecticut Ave., N.W., Washington 6, D. C. 1959. Price—Single copies of this booklet free.

SCIENCE, FOR THE ACADEMICALLY TALENTED STUDENT, by the National Education Association Project on the Academically Talented Student, and the National Association of Science Teachers. Paper. 63 pages. 14.5×22.5 cm. 1959. National Association of Science Teachers, Dept. of the NEA, 1201 Sixteenth Street, N.W., Washington 6, D. C. Price—Single Copy, 60 cents.

THE SUPERVISOR OF MATHEMATICS, HIS ROLE IN THE IMPROVEMENT OF MATHEMATICS INSTRUCTION, by the National Council of Teachers of Mathematics. Paper. 10 pages. 9.5×22.5 cm. 1959. National Council of Teachers of Mathematics, 1201 Sixteenth Street, N.W., Washington 6, D. C. Price 15¢ each; 10 or more, 10¢ each.

HOW TO STUDY SCIENCE, by Louis Haber, *Science Teacher, Post Road School, White Plains, New York*, and Lawrence Samuels, *Consultant in Reading and Study Skills, Cliffside Park, New Jersey.* Paper. 81 pages. 15×22.5 cm. 1959. College Entrance Publications, 104 Fifth Avenue, New Ylrk 11, New York. Price—List price $1.00, School net $.60.

PROGRAM FOR COLLEGE PREPARATORY MATHEMATICS, report of the Commission on Mathematics. Paper. 63 pages. 18×24 cm. 1959. College Entrance Examination Board, c/o Educational Testing Service, Box 592, Princeton, New Jersey. Price $1.00.

ELEMENTARY MATHEMATICS SERIES: SEEING THROUGH ARITHMETIC, by Maurice L. Hartung, Henry Van Engen, and Lois Knowles. All Cloth. 18×22.5 cm. 1959. Scott, Foresman and Company, Chicago, Illinois.

Book 3, 256 pages, price $2.32
Book 4, 256 pages, price $2.32
Book 5, 272 pages, price $2.56
Book 6, 288 pages, price $2.56

TEACHING GUIDE for above books. All paper.

Book 3, 352 pages
Book 4, 368 pages
Book 5, 400 pages
Book 6, 424 pages

A PHILOSOPHER LOOKS AT SCIENCE, by John G. Kemeny, *Professor of Philosophy and Chairman, Department of Mathematics and Astronomy, Dartmouth College.* Cloth. Pages xii+269. 1959. D. Van Nostrand Company, Inc., 257 Fourth Avenue, New York 10, New York 10, New York.

HIGH ALTITUDE AND SATELLITE ROCKETS, by The Royal Aeronautical Society, The British Interplanetary Society, and The College of Aeronautics. Cloth. 136 pages. 21.5×28 cm. 1959. The Philosophical Library, Inc. 15 East 40th Street, New York 16, New York. Price $15.00.

FRESHMAN MATHEMATICS, by Paul K. Rees, *Professor of Mathematics, Louisiana State University.* Cloth. Pages x+285. 15×23 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $4.95.

INTRODUCTORY CALCULUS, by Donald E. Richmond, *Department of Mathematics, Williams College*. Cloth. Pages xv+207. 15×23 cm. 1959. Addison-Wesley Publishing Company, Inc., Reading, Massachusetts. Price $5.50.

COLLEGE ZOOLOGY, by Robert W. Hegner, *Late Professor of Protozoology in the School of Hygiene and Public Health of Johns Hopkins University* and Karl A. Stiles, *Professor and Head, Department of Zoology, Michigan State University*. Cloth. Pages x+726. 17×25 cm. 1959. The Macmillan Company, 60 Fifth Avenue, New York 11, New York. Price $7.50.

FIND A CAREER IN ELECTRONICS, by Wallace West. Cloth. 13×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Avenue, New York City, New York. Price $2.75.

POWER UNLIMITED! by Abraham and Rebecca B. Marcus. Cloth. Pages viii +152. 13.5×20.5 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $3.50.

TOMORROW—THE MOON! by Abraham and Rebecca B. Marcus. Cloth. Pages viii+150. 13.5×20.5 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $3.50.

PLANE TRIGONOMETRY, With Tables, by Gordon Fuller, *Professor of Mathematics, Texas Technological College*. Cloth. Pages xiii+281. 14.5×23 cm. 1959. McGraw-Hill Book Company, Inc., 350 West 42nd Street, New York 36, New York. Price $4.75.

COLLEGE MATHEMATICS FOR FRESHMEN, by Paul K. Smith, *Professor of Mathematics, Louisiana Polytechnic Institute*, and Henry F. Schroeder, *Professor of Mathematics, Louisiana Polytechnic Institute*. Cloth. Pages x+314. 15×23 cm. 1959. D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey. Price $4.25.

FINITE MATHEMATICAL STRUCTURES, by John G. Kemeny, *Professor of Mathematics, Dartmouth College*, Hazleton Mirkil, *Assistant Professor of Mathematics, Dartmouth College*, J. Laurie Snell, *Associate Professor of Mathematics, Dartmouth College*, and Gerald L. Thompson, *Professor of Mathematics, Ohio Wesleyan University*. Cloth. Pages xi+487. 1959. 15×23 cm. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $7.95.

CALCULUS, by Richard E. Johnson and Fred L. Kiokemeister. Cloth. Pages xii+634. 15×23 cm. 1959. Allyn and Bacon, Inc., 150 Tremont Street, Boston, Massachusetts.

FOUNDATIONS OF MATHEMATICS, by Carl H. Denbow and Victor Goedicke, *Professors of Mathematics, Ohio University*. Cloth. Pages xviii+620. 15.5 ×23.5 cm. 1959. Harper & Brothers, 49 East 33rd Street, New York 16, New York. Price $6.00.

JAPAN, Three Epochs of Modern Education, by Ronald S. Anderson, *Specialist in Comparative Education, Far East Countries*. Paper. Pages xii+219. 15×23 cm. 1959. U. S. Department of Health, Education, and Welfare, Office of Education, Washington, D. C. Price $1.25.

EVERYDAY METEOROLOGY, by A. Austin Miller, *Professor of Geography, University of Reading*, and M. Parry, *Lecturer in Geography, University of Reading*. Cloth. 270 pages. 14×23 cm. 1959. Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. Price $7.50.

INTERMEDIATE ALGEBRA, by Lyman M. Kells, *Professor of Mathematics, Emeritus United States Naval Academy*. Cloth. Pages xi+296. 15×23 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $4.95.

THE WORLD OF THE MICROSCOPE, by L. J. Ludovici. Cloth. 128 pages. 15×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, New York. Price $2.95.

PLANE TRIGONOMETRY, by Raymond W. Brink, *Professor Emeritus Department of Mathematics, University of Minnesota.* Cloth. Pages xii+110. 15×23.5 cm. 1959. Appleton-Century-Crofts, Inc., 35 West 32nd Street, New York 1, New York. Price $4.00.

THE UPPER ATMOSPHERE, by H. S. W. MASSEY, and R. L. F. Boyd, *University College, London.* Cloth. Pages xii+333. 14×22.5 cm. 1959. Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. Price $17.50.

THE MAMMALS OF NORTH AMERICA, Volumes I and II, by E. Raymond Hall, *Summerfield Distinguished Professor, Chairman of the Department of Zoology,* and *Directory of the Museum of Natural History, University of Kansas,* and Keith R. Kelson, *Division of Scientific Personnel and Education, National Science Foundation.* Cloth. Pages xxxviii+1083+38. 20×27 cm. 1959. The Ronald Press Company, 15 East 26th Street, New York 10, New York. Price $35.00—2 vol. set.

PLANE GEOMETRY AND SUPPLEMENTS, by Walter W. Hart, *Author of Textbooks for Secondary Mathematics,* Veryl Schult, *Supervising Director, Mathematics Curriculum, Public Schools of Washington, D. C.,* and Henry Swain, *Head of the Mathematics Department, New Trier Township High School, Winnetka, Illinois.* Cloth. Pages ix+454. 15×23.5 cm. 1959. D. C. Heath and Company, 285 Columbus Avenue, Boston 16, Massachusetts. Price $3.80.

THE ROMANCE OF CHEMISTRY, FROM ANCIENT ALCHEMY TO NUCLEAR FISSION, by Keith Gordon Irwin. Cloth. Pages xi+148. 15×23 cm. 1959. The Viking Press, 625 Madison Avenue, New York 22, New York. Price $3.75.

ORGANIC CHEMISTRY, Second Edition, by Melvin J. Astle, *Ph.D., Professor of Organic Chemistry,* and J. Reid Shelton, *Ph.D., Professor of Organic Chemistry.* Cloth. Pages x+771. 15×23 cm. 1959. Harper & Brothers, 49 East 33rd Street, New York 16, New York. Price $7.50.

FRUIT KEY AND TWIG KEY TO TREES AND SHRUBS, by William M. Harlow, *Ph.D., Professor of Wood Technology, State University of New York, College of Forestry, Syracuse, New York.* Paper. 56 pages. 14×21 cm. 1946. Dover Publications, Inc., 180 Varick Street, New York 14, New York. Price $1.25.

CONCISE DICTIONARY OF SCIENCE, by Frank Gaynor. Cloth. 546 pages. 13×20.5 cm. 1959. Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. Price $10.00.

FINANCING PUBLIC SCHOOL FACILITIES, by Clayton D. Hutchins, *Chief of School Finance,* and Elmer C. Deering, *Specialist in Financing School Capital Outlay,* assisted by Albert R. Munse, *Assistant Specialist in School Finance,* and Eugene P. McLoone, *Research Assistant.* Paper. Pages ix+214. 23×29 cm. 1959. U. S. Department of Health, Education, and Welfare, Office of Education, Washington, D. C. Price $1.50.

SYMBOLIC LOGIC AND THE GAME OF LOGIC, by Lewis Carroll. Paper. 13×20 cm. Dover Publications, Inc., 180 Varick Street, New York 14, New York. Price $1.50. Volume I:

Symbolic Logic, Pages xxxi+199
The Game of Logic, Pages 96.

PILLOW PROBLEMS AND A TANGLED TALE, by Lewis Carroll. Paper. 13×20 cm. Dover Publications, Inc., 180 Varick Street, New York 14, New York. Price $1.50. Volume II:

Pillow Problems, Pages xx+109.
A Tangled Tale, Pages 152.

SCIENCE YOU CAN USE, by George K. Stone and Lucy W. Stephenson. Cloth. 383 Pages. 15×23 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $4.40.

WHO LIVES IN A FIELD, by Duryea Morton. Cloth. 127 Pages. 16×21.5 cm. 1959. Coward-McCann, Inc., 210 Madison Avenue, New York City, New York. Price $3.00.

LET'S GO TO A HOSPITAL, by Diana Hammond. Cloth. 47 pages. 20.5×16 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, New York. Price $1.95.

LET'S GO FOR A NATURE WALK, by Joan Rosner. Cloth. 47 pages. 16×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Ave., New York City, New York. Price $1.95.

ALASKA AND SCIENCE EXPERIENCES, by Matthew F. Vessel, and Herbert H. Wong. Paper. 14 pages. 14×22 cm. 1959. Fearon Publisher, 2263 Union Street, San Francisco, California. Price $.75.

INTERMEDIATE ALGEBRA, by Ross H. Bardell and Abraham Spitzbart, *University of Wisconsin, Milwaukee.* Cloth. Pages ix+274. 15×23 cm. 1959. Addison-Wesley Publishing Company, Inc., Reading, Massachusetts. Price $4.75.

THE RADIO AMATEUR'S HANDBOX, by the Headquarters Staff of the American Radio Relay League, West Hartford, Conn. Paper. 125 pages. 16.5×24 cm. 1959. The American Radio Relay League, West Hartford, Conn. Price $3.50.

EDTA TITRATIONS, AN INTRODUCTION TO THEORY AND PRACTICE, by H. A. Flaschka, *Associate Professor of Chemistry, Georgia Institute of Technology, Atlanta, Georgia.* Cloth. 138 pages. 14×21.5 cm. 1959. Pergamon Press Inc., 122 East 55th Street, New York 22, New York. Price $6.50.

THE PHYSICAL SCIENCES, by E. J. Cable, R. W. Getchell, W. H. Kadesch, W. J. Poppy, *Iowa State Teachers College*, and H. E. Crull, *Butler University.* Cloth. Pages xiii+553. 17×24.5 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $6.95.

ELEMENTS OF MODERN MATHEMATICS, by Kenneth O. May, *Department of Mathematics and Astronomy, Carleton College.* Cloth. 15×23 cm. Pages xvi +607. 1959. Addison-Wesley Publishing Company, Inc., Reading, Massachusetts. Price $6.50.

THE STRUCTURE OF THE PHYSICAL UNIVERSE, by Dewey B. Larson. Cloth. Pages v+218. 14.5×22.5 cm. 1959. Dewey B. Larson, 755 N.E. Royal Court, Portland 12, Oregon. Price $6.00.

WORKING WITH PLANTS, by J. Myron Atkin and R. Will Burnett, *University of Illinois.* Paper. Pages vi+58. 15×23 cm. 1959. Rinehart & Company, Inc., New York, New York. Price $1.00.

ENGINEERING DRAWING, by Eugene G. Pare, *State College of Washington.* Cloth. Pages xii+500. 15.5×23 cm. 1959. Henry Holt and Company, 383 Madison Avenue, New York 17, New York. Price $6.50.

FUNDAMENTALS OF PHYSICAL SCIENCE, Fourth Edition, by Konrad Bates Krauskopf, *Professor of Geochemistry, Stanford University.* Cloth. Pages x+653. 15×23 cm. 1959. McGraw-Hill Book Company, Inc., New York, New York.

THE SCHOOL IN AMERICAN SOCIETY, by Ralph L. Pounds, *Professor of Education, University of Cincinnati*, and James R. Bryner, *Superintendent of Schools, North College Hill, Ohio.* Cloth. Pages xxi+518. 15×23 cm. 1959. The Macmillan Company, 60 Fifth Avenue, New York 11, New York. Price $6.75.

ENGINEERING DRAWING PROBLEMS, by E. V. Mochel, *University of Virginia.* Paper. Pages 21.5×29 cm. 1959. Henry Holt and Company, 383 Madison Avenue, New York 17, New York. Price $4.50.

CALCULUS WITH ANALYTIC GEOMETRY, by Angus E. Taylor, *Professor of Mathematics, University of California, Los Angeles.* Cloth. Pages xv+762. 14.5 ×22.5 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $8.50.

A MODERN INTRODUCTION TO COLLEGE MATHEMATICS, by Israel H. Rose, *Associate Professor of Mathematics, University of Massachusetts.* Cloth. Pages xxi+530. 14×22.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $6.50.

INTRODUCTORY COLLEGE MATHEMATICS, by Thomas L. Wade, *Florida State University.* Cloth. Pages xiv+319. 14×22.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $5.50.

FOUNDATIONS OF ADVANCED MATHEMATICS, by William E. Kline, *Supervisor of Testing, Baltimore County Public Schools, Maryland*, Robert Oesterle, *Purdue University, Lafayette, Indiana*, and Leroy M. Willson, *Department of Mathematics, Georgia State College, Atlanta, Georgia.* Cloth. Pages vi+519. 14×22 cm. 1959. American Book Company, 55 Fifth Avenue, New York 3, New York. Price $4.96.

CONTRIBUTIONS TO EDUCATION AS A PROFESSION, Edited by Ole Sand and Elaine Cook. Paper. 31 pages. 16×24 cm. 1959. G. P. Putnam's Sons, 210 Madison Avenue, New York 16, New York.

SECONDARY SCHOOL TEACHING METHODS, by Leonard H. Clark, *Chairman, Department of Secondary Education, School of Education, University of Hartford*, and Irving S. Starr, *Dean, School of Education, University of Hartford.* Cloth. Pages xii+340. 15×23 cm. 1959. The Macmillan Company, 60 Fifth Avenue, New York 11, New York. Price $5.00.

ASTRONOMY, by Theodore G. Mehlin, *Field Memorial Professor of Astronomy, Williams College.* Cloth. Pages viii+392. 14×22.5 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, New York. Price $5.95.

JOURNEY INTO SPACE, by Matthew F. Vessel and Herbert H. Wong. Paper. 14 pages. 13×21 cm. 1959. Fearon Publishers, 2263 Union Street, San Francisco, California. Price $.75.

WATER, A RESOURCE, by Matthew F. Vessel and Herbert H. Wong. Paper. 14 pages. 13×21 cm. 1959. Fearon Publishers, 2263 Union Street, San Francisco, California. Price $.75.

SCIENCE BOOKS 1958, by Matthew F. Vessel and Herbert H. Wong. Paper. 14 pages. 13×21 cm. 1959. Fearon Publishers, 2263 Union Street, San Francisco, California. Price $.75.

EDUCATION OF THE SEVERELY RETARDED CHILD, a Bibliographical Review, prepared by Harold M. Williams, *Specialist, Exceptional Children and Youth, Office of Education*, and J. E. Wallace Wallin, *Retired Director of Special Education Departments, Psycho-Educational Clinics, and Professor of Clinical Psychology.* Paper. Pages iii+26. 14×23 cm. 1959. U. S. Department of Health, Education, and Welfare, Office of Education, Washington, D. C.

SCIENCE TEACHING TECHNIQUES, VII, by the Association of Teachers in Colleges and Departments of Education, the Association of Women Science Teachers, the London Association of Science Teachers, and the Science Masters' Association. Paper. 64 pages. 13.5×21 cm. 1959. John Murray, Albemarle Street, London, W.1, England.

A GUIDE TO VOCATIONS IN ENGINEERING AND RELATED FIELDS, by Lynn L. Ralya, *Ph.D., Specialist in Educational and Vocational Counseling*, and Lillian L. Ralya, *Ph.D., Manager, Counseling and Testing Services Center, University of California Extension, Los Angeles*. Paper. 42 pages. 15×23 cm. 1959. Lynn L. Ralya and Lillian L. Ralya, 907 Fourteenth Street, Santa Monica, California. Price $1.25.

ACTION FOR SCIENCE UNDER NDEA, by the National Science Teachers Association. Paper. 22 pages. 13.5×21 cm. 1959. National Science Teachers Association, 1201—16th Street, N.W., Washington, D. C. Price—Single copies free; quantity orders, 15 cents each.

CAREERS IN SCIENCE TEACHING, by the National Science Teachers Association. Paper. 15×22.5 cm. 1959. National Science Teachers Association, 1201—16th Street, N.W., Washington, D. C. Price—Single Copies, free; quantity orders, 10 cents each.

MATHEMATICS, FOR THE ACADEMICALLY TALENTED STUDENT IN THE SECONDARY SCHOOL, by the National Council of Teachers of Mathematics, and the National Education Association Project on the Academically Talented Student. Paper. 48 pages. 14.5×22.5 cm. 1959. National Council of Teachers of Mathematics, Dept. of the NEA, 1201 Sixteenth Street, N.W., Washington 6, D. C. Price—Single copy, 60 cents.

INTRODUCTION TO THE PHYSICAL SCIENCES, by Morris Goran, *Roosevelt University*. Paper. Pages xiv+421. 21.5×27.5 cm. 1959. The Free Press, Glencoe, Illinois. Price $6.00.

THE GOLDEN BOOK OF ASTRONOMY, by Rose Wyler and Gerald Ames. Cloth. 97 pages. 25×31 cm. 1959. Golden Press, Inc. 630 Fifth Avenue, Rockefeller Center, New York 20, New York. Price $3.95.

MR. WIZARD'S EXPERIMENTS FOR YOUNG SCIENTISTS, by Don Herbert. Cloth. 187 pages. 13×20.5 cm. 1959. Doubleday & Company, Inc., 575 Madison Avenue, New York 22, New York. Price $2.95.

ADVENTURES IN CHEMISTRY, by Nathan Feifer, *Chairman, Department of Physical Science and Chemistry, Jamaica High School, New York*. Paper. 128 pages. 13×20 cm. 1959. Sentinel Books, Publishers, Inc., 112 East 19th Street, New York 3, New York. Price $1.00.

URANIUM AND OTHER MIRACLE METALS, by Fred Reinfeld. Cloth. 128 pages. 16×25 cm. 1959. Sterling Publishing Company, Inc., 419 Fourth Avenue, New York 16, New York. Price $3.95.

MAN AND THE GOOD EARTH, by Anabel Williams-Ellis. Cloth. 64 pages. 12×20 cm. 1959. G. P. Putnam's Sons, 210 Madison Avenue, New York City, New York. Price $2.00.

MATHEMATICS DICTIONARY (Students Edition), edited by Glenn James and Robert C. James. Cloth. 474 pages. 14.5×22.5 cm. 1959. D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey.

PREHISTORIC LIFE, by Matthew F. Vessel and Herbert H. Wong. Paper. 14 pages. 13×21 cm. 1959. Fearon Publishers, 2263 Union Street, San Francisco, California. Price $.75.

ELEMENTS OF RADIO, Fourth Edition, by Abraham Marcus and William Marcus. Cloth. 667 pages. 14.5×22.5 cm. 1959. Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, New York. Price $5.25.

THE GROWTH OF MATHEMATICAL IDEAS, Grades K–12, prepared by the National Council of Teachers of Mathematics. Cloth. Pages x+507. 14.5×22.5 cm. 1959. National Council of Teachers of Mathematics, 1201 Sixteenth Street, N.W., Washington 6, D. C. Price $5.00. To members of the Council $4.00.

PROBLEM SOLVING IN GENERAL CHEMISTRY, by George I. Sackheim. *Department of Chemistry, University of Illinois, Chicago.* Paper. 132 pages. 20.5×27.5 cm. 1959. Row, Peterson and Company, Evanston, Illinois.

APPENDICES TO THE REPORT OF THE COMMISSION ON MATHEMATICS. Paper. Pages viii+231. 17.5×24.5 cm. 1959. College Entrance ExaminationBoard, 425 West 17th Street, New York 27, New York.

Book Reviews

THE ATOM AND THE ENERGY REVOLUTION, by Norman Lansdell. Cloth. 200 pages 15.5×23.5 cm. 1958. Philosophical Library, Inc., 15 East 40th Street, New York 16, New York. Price $6.00.

The past 150 years has been known as a period of great progress and industrial scientific advancement. The success of this progress has been due mainly to man's ability to make wide use of the various energy resources, namely, fossilized energy including coal, petroleum, and natural gas.

In part I of this book, the author takes inventory of the world energy resources and observes that at the present rate of consumption they will soon be gone. He calls attention to the population explosion and concludes that the rate of energy consumption will probably double in the next fifty years.

In part II he discusses other possible sources of energy; such as, solar energy and atomic energy. The remainder of the book deals with the future uses of atomic energy. Subjects covered include: the atom, its energy and methods of releasing it; material sources of atomic energy; its exploitation by separate countries and by international bodies; and its impact in the world as a whole. The problem of radiation risks and insurance against them is also treated.

The author has included a large collection of valuable facts. Furthermore, the organization is very good. Any physical science teacher of either high school or junior college level would profit by having this book on his personal shelf as a source of valuable information.

GERALD OSBORN
Western Michigan University
Kalamazoo, Michigan

BASIC GENERAL MATHEMATICS, by Margaret Joseph, *Chairman, Mathematics Department, Shorewood High School, Milwaukee, Wisconsin,* and Mildred Keiffer, *Supervisor of Secondary Mathematics, Cincinnati Public Schools, Cincinnati, Ohio.* Cloth cover. iv+458. 23×15 cm. 1958. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

This book was written to give those students who have completed one year of general mathematics in high school an opportunity to take further mathematics. The book is well written with some splendid working photographs that complement the text material. There are plenty of good problems of both story and drill type. It is written to the student, is filled with thought provoking questions and uses a vocabulary with which he is familiar. In cases where this isn't possible the meaning of the new words is developed.

The content is variable. The number system is discussed but the discussion does not develop the nature of the system. This reviewer feels this is a weakness in the text. Measurement is included and the authors have done very well with precision, standard units of measure, tolerance, etc. This is a good section.

The algebra of the text really revolves about the formula and little is done with the nature of generalized numbers. For a text with the purpose of this one it is probably better to do only formulae.

In the work dealing with Euclidean geometry it seems there is more repetition than necessary of what ordinarily appears in most first year general mathematics books. The same can be said of the chapters on graphs and taxes.

The work included in the chapters on buying, consumer credit and insurance is well done and goes beyond most texts in general mathematics.

There are two interesting chapters not usually found, namely, sports and transportation. These apply mathematics to many situations in the two areas. I am certain the students for whom this text is written will be interested.

The text is very teachable and perhaps the apparent duplication of previous work mentioned above is needed for many of the students who will enroll. This book will fill a need for a second year of non-traditional mathematics for the terminal student.

PHILIP PEAK
Indiana University
Bloomington, Indiana

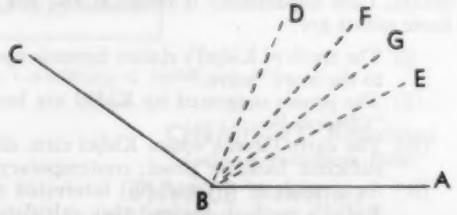
THE KIDJEL RATIO, by Maurice Kidjel, *Hawaii Art Publishing Co., Honolulu, Hawaii.*

Has Maurice Kidjel finally solved the "3 Impossibles" of classical constructions with compass and straightedge only? Will you be able to solve them if you send your dollar in reply to the advertisement? The answers to the questions depend upon what you mean by "solve." If you accept an answer because it "looks right," you will accept Kidjel's method of solution. You will also accept the statement

$$\tfrac{1}{2}=\tfrac{1}{4}-\tfrac{1}{8}+\tfrac{1}{16}-\tfrac{1}{16}=0.3125.$$

To use this statement as a basis for trisecting an angle ABC, you

(a) bisect $\angle ABC$ with BD;
(b) bisect ABD with BE;
(c) bisect $\angle EBD$ with BF; and
(d) bisect EBF with BG.



Then BG will appear to trisect $\angle ABC$. In other words, when you apply the only test apparently recognized by Kidjel, i.e., "Draw your own,," BG appears to trisect $\angle ABC$ or at least comes so close that you think that any error could be yours.

Does BG trisect $\angle ABC$? In this case you know that

$$<ABG=0.3125(\angle ABC)$$

instead of $\frac{1}{3}\angle ABC$. Does $0.3125=\frac{1}{3}$? You may say "Yes, for all practical purposes." But does $0.3125=0.3333\cdots$? Well, if we insist on an exact statement, No.

These same statements apply to Kidjel's methods. If you simply want a method for trisecting angles that looks all right, use Kidjel's method; OR better still, use the easier one just given which, for many angles, has less than half the error

of Kidjel's. If you use the word "solve" to mean "solve exactly" rather than "solve approximately so that there are no obvious errors," then the "3-Impossibles" have not been solved by Kidjel.

The early Greeks were purists. They used "solve" to mean "solve exactly." They would probably have enjoyed seeing Kidjel's method as a good sporting "attack" on the problem. They would not have accepted his solution. The same is true today. The people who accept 0.3125 times a quantity as one-third of it because the result "appears" to be the same accept "Kidjel's solutions"; the people who recognize the purist ideas of the early Greeks reject "Kidjel's solutions" because only approximations to the correct answer are obtained. In other words, good approximations are not enough.

Let us now consider the second of the initial questions—Will you be able to solve the "3 Impossibles" if you send your dollar? Obviously you will not be able to do any more than Kidjel; you will at best be able to make good approximations for the constructions. What will you get for your money? You may expect:

(1) an 8½ by 11 sheet with one side covered with generalities; the other side entitled "The 3-impossible solved with compass and straight-edge only." The explanation for trisecting an angle is given in 8 lines; that for squaring a circle in 10 lines; that for doubling the cube in 10 lines. Each line is about 3 in. long. Each explanation consists solely of "Do this" types of statements and statements of the results obtained. There are no reasons given. The only hint of a proof is the admonition "Draw your own."

(2) a copy of a page (p. 52) from the book "The 2 hours that shook the mathematical world" essentially repeating the construction for trisecting an angle. This time the list of steps that you are to follow as you "Draw your own" has the heading "Geometric proof of Kidjel's method . . . " and concludes with "Observe! . . ." The sole basis recognized for proof appears to be observation.

(3) an announcement of the book mentioned in (2) inviting you to send for "the complete text with Kidjel's ratio caliper, only $15.00 per set. The book has 101 pages, mostly drawings; the calipers have a wide range and can be used to make constructions well enough to observe the errors when trisections of large angles (nearly 180°) are attempted.

Mathematicians are concerned with logical truth or, as they say, valid statements. Cold impartiality is essential and has been sought in this review. The basic points are:

(i) The truth of Kidjel's claims depends upon the meaning which is attached to the word "solve."

(ii) The proofs suggested by Kidjel are based upon "Draw your own" and "Observe."

(iii) The early Greeks whom Kidjel cites did not recognize observation as a sufficient basis for proof; contemporary mathematicians do not either.

(iv) As a result of (ii) and (iii) interested mathematicians do not recognize Kidjel's method. Instead they calculate the percent of error for various sizes of angle. For example, one mathematician has written that for an angle of 180° the error is about 5.4%.

(v) There appear to be no grounds for agreement between Kidjel and the mathematicians since neither recognizes the other's assumptions. The only point that seems worthy of emphasis for the lay public is that Plato and the other early Greeks who formulated the "3 Impossibles" interpreted the word "solve" as "solve exactly" just as the mathematicians do today. From this point of view Kidjel's claims are based upon a misunderstanding of the problems; his solutions are simply approximations of the solutions.

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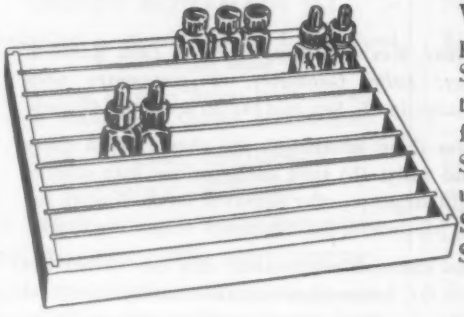

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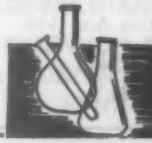

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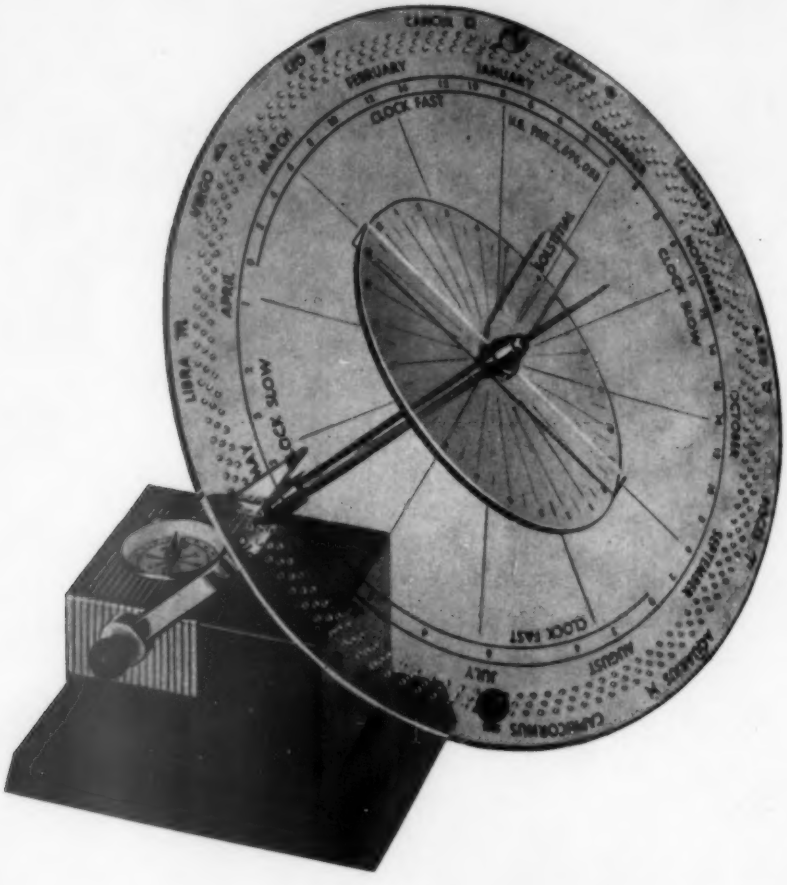

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